GENERAL APPLICATION STRUCTURAL STORMWATER CONTROLS

3.2.1 Stormwater Ponds

General Application
Structural Stormwater Control

Description: Constructed stormwater retention basin that has a permanent pool (or micropool). Runoff from each rain event is detained and treated in the pool primarily through settling and biological uptake mechanisms.

KEY CONSIDERATIONS

DESIGN CRITERIA:

- Minimum contributing drainage area of 25 acres; 10 acres for micropool ED pond
- A sediment forebay or equivalent upstream pretreatment must be provided
- Minimum length to width ratio for the pond is 1.5:1
- Maximum depth of the permanent pool should not exceed 8 feet
- Side slopes to the pond should not exceed 3:1 (h:v)

ADVANTAGES / BENEFITS:

- Moderate to high removal rate of urban pollutants
- High community acceptance
- Opportunity for wildlife habitat

DISADVANTAGES / LIMITATIONS:

- Potential for thermal impacts / downstream warming
- Dam height restrictions for high relief areas
- Pond drainage can be problematic for low relief terrain

MAINTENANCE REQUIREMENTS:

- Remove debris for inlet and outlet structures
- Maintain side slopes / remove invasive vegetation
- Monitor sediment accumulation and remove periodically

POLLUTANT REMOVAL

80%	**Total Suspended Solids**
50 / 30%	**Nutrients –** Total Phosphorus / Total Nitrogen removal
50%	**Metals** – Cadmium, Copper, Lead, and Zinc removal
70%	**Pathogens** – Coliform, Streptococci, E.Coli removal

STORMWATER MANAGEMENT SUITABILITY

- ☑ **Water Quality**
- ☑ **Channel Protection**
- ☑ **Overbank Flood Protection**
- ☑ **Extreme Flood Protection**

Accepts Hotspot Runoff: *Yes*
(2 feet of separation distance required to water table)

FEASIBILITY CONSIDERATIONS

M - H	**Land Requirement**
L	**Capital Cost**
L	**Maintenance Burden**

Residential Subdivision Use: *Yes*

High Density / Ultra – Urban: *No*

Drainage Area: *10 – 25 acres min.*

Soils: *Hydrologic group 'A' and 'B' soils may require pond liner*

Other Considerations:

- *Outlet Clogging*
- *Safety Bench*
- *Landscaping*

L=Low **M**=Moderate **H**=High

3.2.1.1 General Description

Stormwater ponds (also referred to as *retention ponds*, *wet ponds*, *or wet extended detention ponds*) are constructed stormwater retention basins that have a permanent (dead storage) pool of water throughout the year. They can be created by excavating an already existing natural depression or through the construction of embankments.

In a stormwater pond, runoff from each rain event is detained and treated in the pool through gravitational settling and biological uptake until it is displaced by runoff from the next storm. The permanent pool also serves to protect deposited sediments from resuspension. Above the permanent pool level, additional temporary storage (live storage) is provided for runoff quantity control. The upper stages of a stormwater pond are designed to provide extended detention of the 2-year storm for downstream channel protection, as well as normal detention of larger storm events (50-year and, optionally, the 100-year storm event).

Stormwater ponds are among the most cost-effective and widely used stormwater practices. A well-designed and landscaped pond can be an aesthetic feature on a development site when planned and located properly.

There are several different variants of stormwater pond design, the most common of which include the wet pond, the wet extended detention pond, and the micropool extended detention pond. In addition, multiple stormwater ponds can be placed in series or parallel to increase performance or meet site design constraints. Below are descriptions of each design variant:

- **Wet Pond** – Wet ponds are stormwater basins constructed with a permanent (dead storage) pool of water equal to the water quality volume. Stormwater runoff displaces the water already present in the pool. Temporary storage (live storage) can be provided above the permanent pool elevation for larger flows.
- **Wet Extended Detention (ED) Pond** – A wet extended detention pond is a wet pond where the water quality volume is split evenly between the permanent pool and extended detention (ED) storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 24 hours. This design has similar pollutant removal to a traditional wet pond, but consumes less space.
- **Micropool Extended Detention (ED) Pond** – The micropool extended detention pond is a variation of the wet ED pond where only a small “micropool” is maintained at the outlet to the pond. The outlet structure is sized to detain the water quality volume for 24 hours. The micropool prevents resuspension of previously settled sediments and also prevents clogging of the low flow orifice.
- **Multiple Pond Systems** – Multiple pond systems consist of constructed facilities that provide water quality and quantity volume storage in two or more cells. The additional cells can create longer pollutant removal pathways and improved downstream protection.

Figure 3.2.1-1 shows a number of examples of stormwater pond variants. Section 3.2.1.8 provides plan view and profile schematics for the design of a wet pond, wet extended detention pond, micropool extended detention pond, and multiple pond system.

Conventional dry detention basins do not provide a permanent pool and are not recommended for general application use to meet water quality criteria, as they fail to demonstrate an ability to meet the majority of the water quality goals. In addition, dry detention basins are prone to clogging and resuspension of previously settled solids and require a higher frequency of maintenance than wet ponds if used for untreated stormwater flows. These facilities can be used in combination with appropriate water quality controls to provide channel protection, and overbank and extreme flood storage. Please see a further discussion in subsection 3.4.1 (Dry Detention Basins).

Wet Pond

Wet ED Pond

Micropool ED Pond

Wet ED Pond

Figure 3.2.1-1 Stormwater Pond Examples

3.2.1.2 Stormwater Management Suitability

Stormwater ponds are designed to control both stormwater quantity and quality. Thus, a stormwater pond can be used to address all of the *unified stormwater sizing criteria* for a given drainage area.

Water Quality

Ponds treat incoming stormwater runoff by physical, biological, and chemical processes. The primary removal mechanism is gravitational settling of particulates, organic matter, metals, bacteria and organics as stormwater runoff resides in the pond. Another mechanism for pollutant removal is uptake by algae and wetland plants in the permanent pool—particularly of nutrients. Volatilization and chemical activity also work to break down and eliminate a number of other stormwater contaminants such as hydrocarbons.

Section 3.2.1.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

Channel Protection

A portion of the storage volume above the permanent pool in a stormwater pond can be used to provide control of the channel protection volume (Cp_v). This is accomplished by releasing the 2-year, 24-hour storm runoff volume over 24 hours (extended detention).

Overbank Flood Protection

A stormwater pond can also provide storage above the permanent pool to reduce the post-development peak flow of the 50-year storm (Q_p) to pre-development levels (detention).

Extreme Flood Protection

In situations where it is required, stormwater ponds can also be used to provide detention to control the 100-year storm peak flow (Q_f). Where this is not required, the pond structure is designed to safely pass extreme storm flows.

3.2.1.3 Pollutant Removal Capabilities

All of the stormwater pond design variants are presumed to be able to remove 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed ponds can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or “treatment train” approach.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – 50%**
- **Total Nitrogen – 30%**
- **Fecal Coliform – 70% (if no resident waterfowl population present)**
- **Heavy Metals – 50%**

3.2.1.4 Application and Site Feasibility Criteria

Stormwater ponds are generally applicable to most types of new development and redevelopment, and can be used in both residential and nonresidential areas. Ponds can also be used in retrofit situations. The following criteria should be evaluated to ensure the suitability of a stormwater pond for meeting stormwater management objectives on a site or development.

Discussion

- Suitable for Residential Subdivision Usage – YES
- Suitable for High Density/Ultra-Urban Areas – Land requirements may preclude use
- Regional Stormwater Control – YES

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – A minimum of 25 acres is needed for wet pond and wet ED pond to maintain a permanent pool, 10 acres minimum for micropool ED pond. A smaller drainage area may be acceptable with an adequate water balance and anti-clogging device.
- Space Required – Approximately 2 to 3% of the tributary drainage area
- Site Slope – There should be more than 15% slope across the pond site.
- Minimum Head – Elevation difference needed at a site from the inflow to the outflow: 6 to 8 feet
- Minimum Depth to Water Table – If used on a site with an underlying water supply aquifer or when treating a hotspot, a separation distance of 2 feet is required between the bottom of the pond and the elevation of the seasonally high water table.
- Soils – Underlying soils of hydrologic group “C” or “D” should be adequate to maintain a permanent pool. Most Group A soils and some Group B soils will require a pond liner. *Evaluation of soils should be based upon an actual subsurface analysis and permeability tests*.

3.2.1.5 Planning and Design Criteria

The following criteria are to be considered ***minimum*** *standards for the design of a stormwater pond facility. Consult with Columbia County to determine if there are any variations to these criteria or additional standards that must be followed.*

A. LOCATION AND SITING

- Stormwater ponds should have a minimum contributing drainage area of 25 acres or more for wet pond or wet ED pond to maintain a permanent pool. For a micropool ED pond, the minimum drainage area is 10 acres. A smaller drainage area can be considered when water availability can be confirmed (such as from a groundwater source or areas with a high water table). In these cases a water balance may be performed (see subsection 2.1.8 for details). Ensure that an appropriate anti-clogging device is provided for the pond outlet.
- A stormwater pond should be sited such that the topography allows for maximum runoff storage at minimum excavation or construction costs. Pond siting should also take into account the location and use of other site features such as buffers and undisturbed natural areas and should attempt to aesthetically "fit" the facility into the landscape. Bedrock close to the surface may prevent excavation.
- Stormwater ponds should not be located on steep (>15%) or unstable slopes.
- Stormwater ponds shall not be located within a stream or any other navigable waters of the U.S.
- Minimum setback requirements for stormwater pond facilities:
  - From a property line – 10 feet
  - From a private well – 100 feet; if well is downgradient from a hotspot land use, then the minimum setback is 250 feet
  - From a septic system tank/leach field – 50 feet
  - From utilities – 10 feet
- All utilities should be located outside of the pond/basin site.

B. GENERAL DESIGN

- A well-designed stormwater pond consists of:
  (1) Permanent pool of water,
  (2) Overlying zone in which runoff control volumes are stored, and
  (3) Shallow littoral zone (aquatic bench) along the edge of the permanent pool that acts as a biological filter.
- In addition, **all stormwater pond designs need to include a sediment forebay at the inflow** to the basin to allow heavier sediments to drop out of suspension before the runoff enters the permanent pool. (A sediment forebay schematic can be found in Appendix C)
- Additional pond design features include an **emergency spillway, maintenance access, safety bench, pond buffer, and appropriate native landscaping**.

Figures 3.2.1-4 thru 3.2.1-7 in subsection 3.2.1.8 provides plan view and profile schematics for the design of a wet pond, wet ED pond, micropool ED pond and multiple pond system.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

In general, pond designs are unique for each site and application. However, there are number of geometric ratios and limiting depths for pond design that must be observed for adequate pollutant removal, ease of maintenance, and improved safety.

- Permanent pool volume is typically sized as follows:
  - Standard wet ponds: 100% of the water quality treatment volume (1.0 WQ_v)
  - Wet ED ponds: 50% of the water quality treatment volume (0.5 WQ_v)
  - Micropool ED ponds: Approximately 0.1 inch per impervious acre
- Proper geometric design is essential to prevent hydraulic short-circuiting (unequal distribution of inflow), which results in the failure of the pond to achieve adequate levels of pollutant removal. The minimum length-to-width ratio for the permanent pool shape is 1.5:1, and should ideally be greater than 3:1 to avoid short-circuiting. In addition, ponds should be wedge-shaped when possible so that flow enters the pond and gradually spreads out, improving the sedimentation

process. Baffles, pond shaping or islands can be added within the permanent pool to increase the flow path.

- Maximum depth of the permanent pool should generally not exceed 8 feet to avoid stratification and anoxic conditions. Minimum depth for the pond bottom should be 3 to 4 feet. Deeper depths near the outlet will yield cooler bottom water discharges that may mitigate downstream thermal effects.
- Side slopes to the pond should not usually exceed 3:1 (h:v) without safety precautions or if mowing is anticipated and should terminate on a safety bench (see Figure 3.2.1-2). The safety bench requirement may be waived if slopes are 4:1 or gentler.
- The perimeter of all deep pool areas (4 feet or greater in depth) should be surrounded by two benches: safety and aquatic. For larger ponds, a safety bench extends approximately 15 feet outward from the normal water edge to the toe of the pond side slope. The maximum slope of the safety bench should be 6%. An aquatic bench extends inward from the normal pool edge (15 feet on average) and has a maximum depth of 18 inches below the normal pool water surface elevation (see Figure 3.2.1-2).
- The contours and shape of the permanent pool should be irregular to provide a more natural landscaping effect.

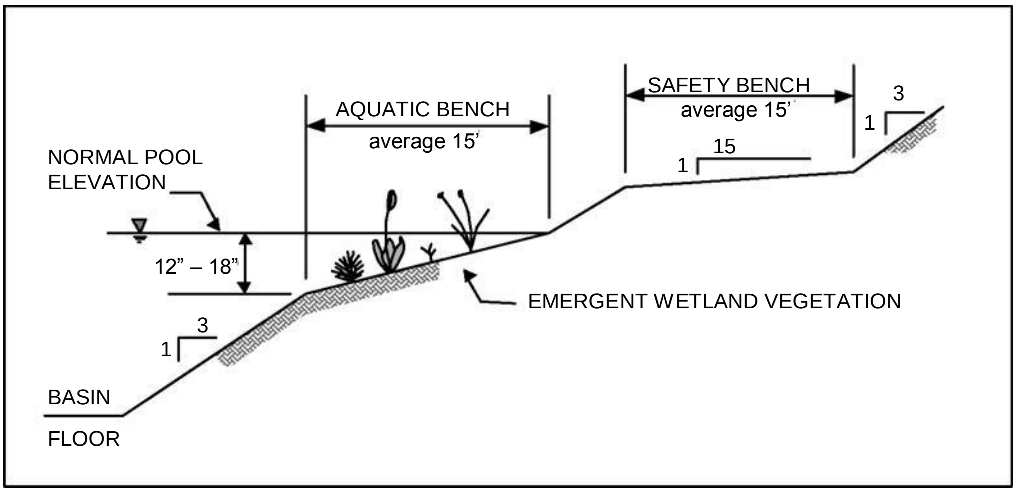


Figure 3.2.1-2 Typical Stormwater Pond Geometry Criteria

D. PRETREATMENT / INLETS

- Each pond should have a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal in a larger permanent pool. The forebay should consist of a separate cell, formed by an acceptable barrier. A forebay is to be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond. In some design configurations, the pretreatment volume may be located within the permanent pool.
- The forebay is sized to contain 0.1 inches per impervious acre of contributing drainage and should be 4 to 6 feet deep. The pretreatment storage volume is part of the total WQ_v requirement and may be subtracted from WQ_v for permanent pool sizing.
- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels are to be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the pond can be partially submerged. Exit velocities from the forebay must be non-erosive.

E. OUTLET STRUCTURES

- Flow control from a stormwater pond is typically accomplished with the use of a concrete or corrugated metal riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base of the pond with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment (see Figure 3.2.1-3). The riser should be located within the embankment for maintenance access, safety and aesthetics.

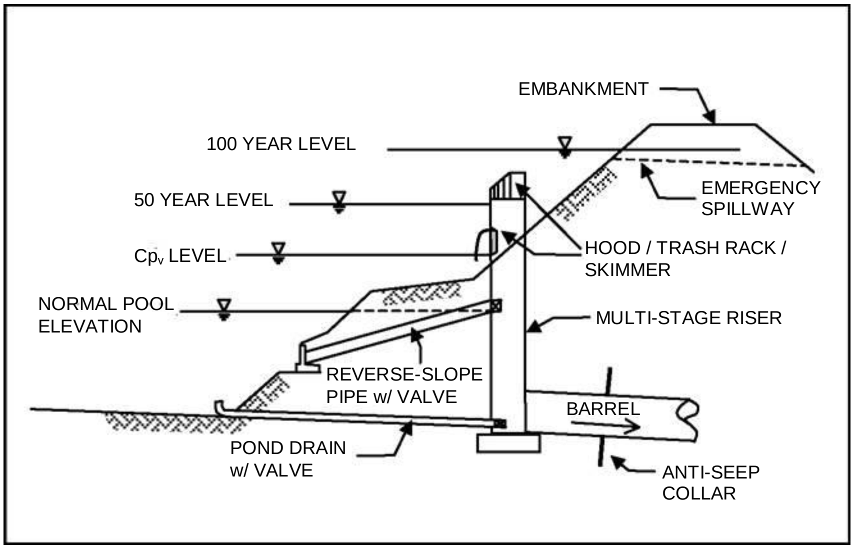


Figure 3.2.1-3 Typical Pond Outlet Structure

- A number of outlets at varying depths in the riser provide internal flow control for routing of the water quality, channel protection, and overbank flood protection runoff volumes. The number of orifices can vary and is usually a function of the pond design.

  For example, a wet pond riser configuration is typically comprised of a channel protection outlet (usually an orifice) and overbank flood protection outlet (often a slot or weir). The channel protection orifice is sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some cold water streams). Since the water quality volume is fully contained in the permanent pool, no orifice sizing is necessary for this volume. As runoff from a water quality event enters the wet pond, it simply displaces that same volume through the channel protection orifice. Thus an off-line wet pond providing *only* water quality treatment can use a simple overflow weir as the outlet structure.

  In the case of a wet ED pond or micropool ED pond, there is generally a need for an additional outlet (usually an orifice) that is sized to pass the extended detention water quality volume that is surcharged on top of the permanent pool. Flow will first pass through this orifice, which is sized to release the water quality ED volume in 24 hours. The preferred design is a reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the pond. The next outlet is sized for the release of the channel protection storage volume. The outlet (often an orifice) invert is located at the maximum elevation associated with the extended detention water quality volume and is sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some cold water streams).

  Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested rectangular, V-notch, proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool.

- The water quality outlet (if design is for a wet ED or micropool ED pond) and channel protection outlet should be fitted with adjustable gate valves or other mechanism that can be used to adjust detention time.

- Higher flows (overbank and extreme flood protection) flows pass through openings or slots protected by trash racks further up on the riser.

- After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars should be installed on the outlet barrel to reduce the potential for pipe failure.
- Riprap, plunge pools or pads, or other energy dissipators are to be placed at the outlet of the barrel to prevent scouring and erosion. If a pond daylights to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. See Section 4.5 (*Energy Dissipation Design*) for more guidance.
- Each pond must have a bottom drain pipe with an adjustable valve that can completely or partially drain the pond within 24 hours.
- The pond drain should be sized one pipe size greater than the calculated design diameter. The drain valve is typically a handwheel activated knife or gate valve. Valve controls shall be located inside of the riser at a point where they (a) will not normally be inundated and (b) can be operated in a safe manner.

See the design procedures in 3.2.1.6 as well as Section 2.2 (*Storage Design*) and Section 2.3 (*Outlet Structures*) for additional information and specifications on pond routing and outlet works.

F. EMERGENCY SPILLWAY

- An emergency spillway is to be included in the stormwater pond design to safely pass the extreme flood flow. The spillway prevents pond water levels from overtopping the embankment and causing structural damage. The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.
- A minimum of 1 foot of freeboard must be provided, measured from the top of the water surface elevation for the extreme flood to the lowest point of the dam embankment, not counting the emergency spillway.

G. MAINTENANCE ACCESS

- A maintenance right of way or easement at least 20 feet wide must be provided to a pond from a public or private road. Maintenance access should be at least 16 feet wide, having a maximum slope of no more than 15%, and be appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access must extend to the forebay, safety bench, riser, and outlet and, to the extent feasible, be designed to allow vehicles to turn around.
- Access to the riser is to be provided with manhole steps within easy reach of valves and other controls.

H. SAFETY FEATURES

- All embankments and spillways must be designed to State of Georgia guidelines for dam safety.
- Fencing of ponds is not generally desirable, but may be required by Columbia County. A preferred method is to manage the contours of the pond through the inclusion of a safety bench (see above) to eliminate drop-offs and reduce the potential for accidental drowning. In addition, the safety bench may be landscaped to deter access to the pool.
- The principal spillway opening should not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent access. Warning signs should be posted near the pond to prohibit swimming and fishing in the facility.

I. LANDSCAPING

- Aquatic vegetation can play an important role in pollutant removal in a stormwater pond. In addition, vegetation can enhance the appearance of the pond, stabilize side slopes, serve as wildlife habitat, and can temporarily conceal unsightly trash and debris. Therefore, wetland plants should be encouraged in a pond design, along the aquatic bench (fringe wetlands), the safety bench and side slopes (ED ponds), and within shallow areas of the pool itself. The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within 6 inches (plus or minus) of the normal pool elevation. Additional information on establishing wetland vegetation and appropriate wetland species for Georgia can be found in Appendix F (*Landscaping and Aesthetics Guidance)*.

- Woody vegetation may not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- A pond buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond. The pond buffer should be contiguous with other buffer areas that are required by existing regulations (e.g., stream buffers) or that are part of the overall stormwater management concept plan. No structures should be located within the buffer, and an additional setback to permanent structures may be provided.
- Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To discourage resident geese populations, the buffer can be planted with trees, shrubs and native ground covers.
- The soils of a pond buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration and therefore may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites and backfill these with uncompacted topsoil.
- Fish such as Gambusia can be stocked in a pond to aid in mosquito prevention.
- A fountain or solar-powered aerator may be used for oxygenation of water in the permanent pool.
- Compatible multi-objective use of stormwater pond locations is strongly encouraged.

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- <u>Low Relief</u> – Maximum normal pool depth is limited; providing pond drain can be problematic
- <u>High Relief</u> – Embankment heights restricted

Soils

- Hydrologic group “A” soils generally require pond liner; group “B” soils may require infiltration testing

Special Downstream Watershed Considerations

- <u>Aquifer Protection</u> – Reduce potential groundwater contamination by preventing infiltration of hotspot runoff. May require liner for type “A” and “B” soils; pretreat hotspots; 2 to 4 foot separation distance from water table
- <u>Swimming Area/Shellfish</u> – Design for geese prevention (see Appendix F); provide 48-hour ED for maximum Coliform die-off.

3.2.1.6 Design Procedures

Step 1: Compute runoff control volumes from the Unified Stormwater Sizing Criteria.

A. Calculate the Water Quality Volume (WQ_v), Channel Protection Volume (Cp_v), Overbank Flood Protection Volume (Q_p), and the Extreme Flood Volume (Q_f).

B. Details on the Unified Stormwater Sizing Criteria are found in Section 1.3.

Step 2: Determine if the development site and conditions are appropriate for the use of a stormwater pond.

A. Consider the Application and Site Feasibility Criteria in subsections 3.2.1.4 and 3.2.1.5-A (Location and Siting).

Step 3: Confirm Columbia County's design criteria and applicability.

- **A.** Consider any special site-specific design conditions/criteria from subsection 3.2.1.5-J. (Additional Site-Specific Design Criteria and Issues).
- **B.** Check with Columbia County officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4: Determine pretreatment volume.

- **A.** A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond. The forebay should be sized to contain 0.1 inches per impervious acre of contributing drainage and should be 4 to 6 feet deep. The forebay storage volume counts toward the total WQ_v requirement and may be subtracted from the WQ_v for subsequent calculations.

Step 5: Determine permanent pool volume (and water quality ED volume).

- **A.** *Wet Pond:* Size permanent pool volume to 1.0 WQ_v
- **B.** *Wet ED Pond:* Size permanent pool volume to 0.5 WQ_v. Size extended detention volume to 0.5 WQ_v.
- **C.** *Micropool ED Pond:* Size permanent pool volume to 25 to 30% of WQ_v. Size extended detention volume to remainder of WQ_v.

Step 6: Determine pond location and preliminary geometry. Conduct pond grading and determine storage available for permanent pool (and water quality extended detention if wet ED pond or micropool ED pond).

- **A.** This step involves initially grading the pond (establishing contours) and determining the elevation-storage relationship for the pond.
  - Include safety and aquatic benches.
  - Set WQ_v permanent pool elevation (and WQ_v-ED elevation for wet ED and micropool ED pond) based on volumes calculated earlier.
- **B.** See subsection 3.2.1.5-C (Physical Specifications / Geometry) for more details.

Step 7: Compute extended detention orifice release rate(s) and size(s), and establish Cp_v elevation.

- **A.** *Wet Pond* The Cp_v elevation is determined from the stage-storage relationship and the orifice is then sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some cold water streams). The channel protection orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool, is a recommended design. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wirecloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter.
- **B.** *Wet ED Pond and Micropool ED Pond* Based on the elevations established in Step 6 for the extended detention portion of the water quality volume, the water quality orifice is sized to release this extended detention volume in 24 hours. The water quality orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool, is a recommended design. Adjustable gate valves can also be used to achieve this equivalent diameter. The Cp_v elevation is then determined from the stage-storage relationship. The invert of the channel protection orifice is located at the water quality extended detention elevation, and the orifice is sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some cold water streams).

Step 8: Calculate Q_{p50} (50-year storm) release rate and water surface elevation.

- **A.** Set up a stage-storage-discharge relationship for the control structure for the extended detention orifice(s) and the 50-year storm.

Step 9: Design embankment(s) and spillway(s).

A. Size emergency spillway, calculate 100-year water surface elevation, set top of embankment elevation, and analyze safe passage of the Extreme Flood Volume (Q_f).

B. At final design, provide safe passage for the 100-year event.

Step 10: Investigate potential pond hazard classifications.

A. The design and construction of stormwater management ponds are required to follow the latest version of the State of Georgia dam safety rules.

Step 11: Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

A. See subsection 3.2.1.5-D through H for more details.

Step 12: Prepare Vegetation and Landscaping Plan.

A. A landscaping plan for a stormwater pond and its buffer should be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation.

B. See subsection 3.2.1.5-I (Landscaping) and Appendix F for more details.

See Appendix D-1 for a Stormwater Pond Design Example

3.2.1.7 Inspection and Maintenance Requirements

Activity	Schedule
• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Monthly
• If wetland components are included, inspect for invasive vegetation.	Semiannual Inspection
• Inspect for damage, paying particular attention to the control structure. • Check for signs of eutrophic conditions. • Note signs of hydrocarbon build-up, and remove appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational. • Check all control gates, valves or other mechanical devices.	Annual Inspection
• Repair undercut or eroded areas.	As Needed
• Perform wetland plant management and harvesting.	Annually (if needed)
• Remove sediment from the forebay.	5 to 7 years or after 50% of the total forebay capacity has been lost
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, or the pond becomes eutrophic.	10 to 20 years or after 25% of the permanent pool volume has been lost

Table 3.2.1-1 Typical Maintenance Activities for Ponds
(Source: WMI, 1997)

Additional Maintenance Considerations and Requirements

- A sediment marker should be located in the forebay to determine when sediment removal is required.
- Sediments excavated from stormwater ponds that do not receive runoff from designated hotspots are not considered toxic or hazardous material and can be safely disposed of by either land application or landfilling. Sediment testing may be required prior to sediment disposal when a hotspot land use is present.
- Periodic mowing of the pond buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest.
- Care should be exercised during pond drawdowns to prevent downstream discharge of sediments, anoxic water, or high flows with erosive velocities. Columbia County should be notified before draining a stormwater pond.

> Regular inspection and maintenance is critical to the effective operation of stormwater ponds as designed. Maintenance responsibility for this BMP should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval. **Columbia County will not accept ownership of or maintain this type of BMP.**

3.2.1.8 Example Schematics

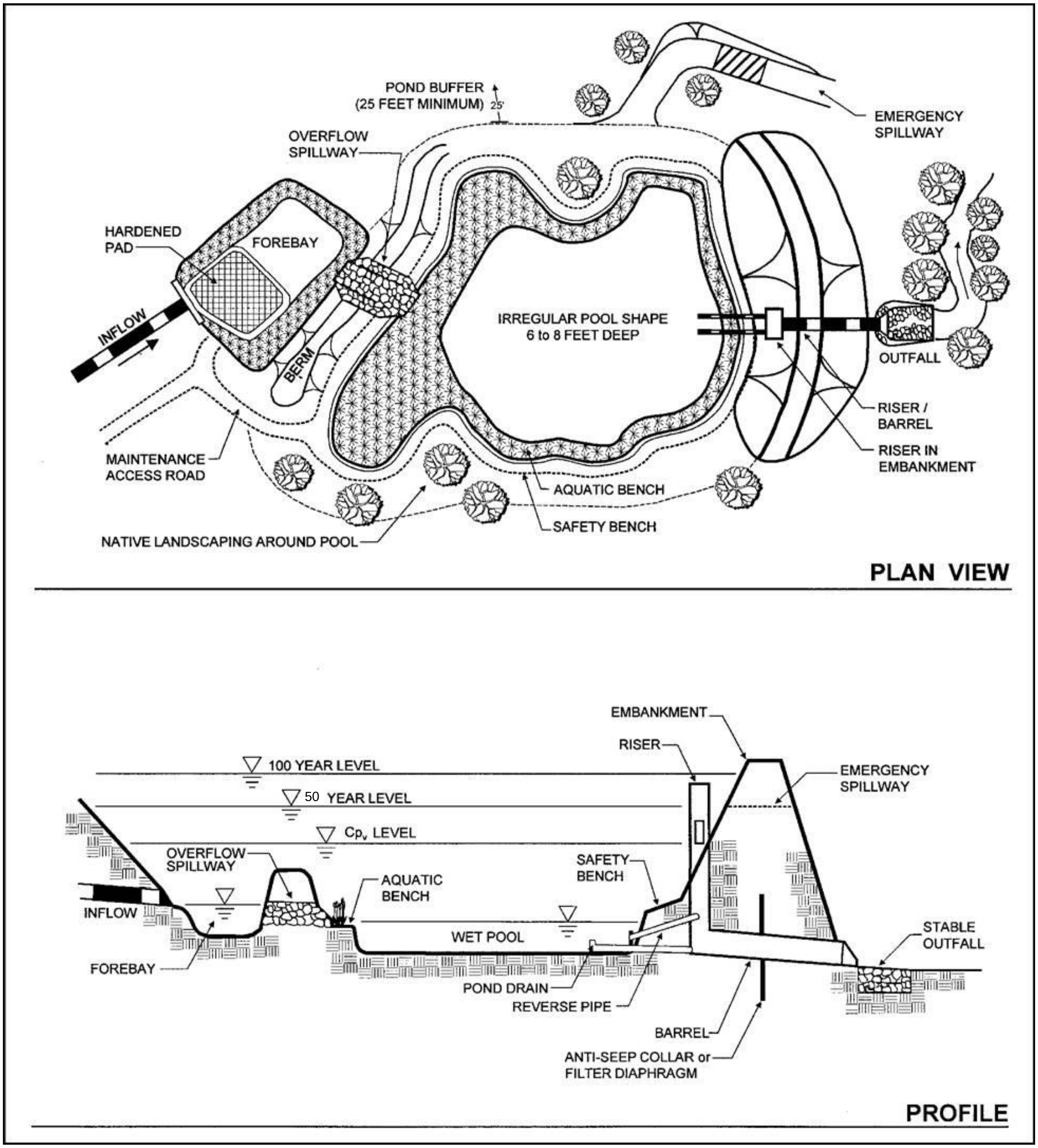


Figure 3.2.1-4 Schematic of Wet Pond
(Source: Center for Watershed Protection)

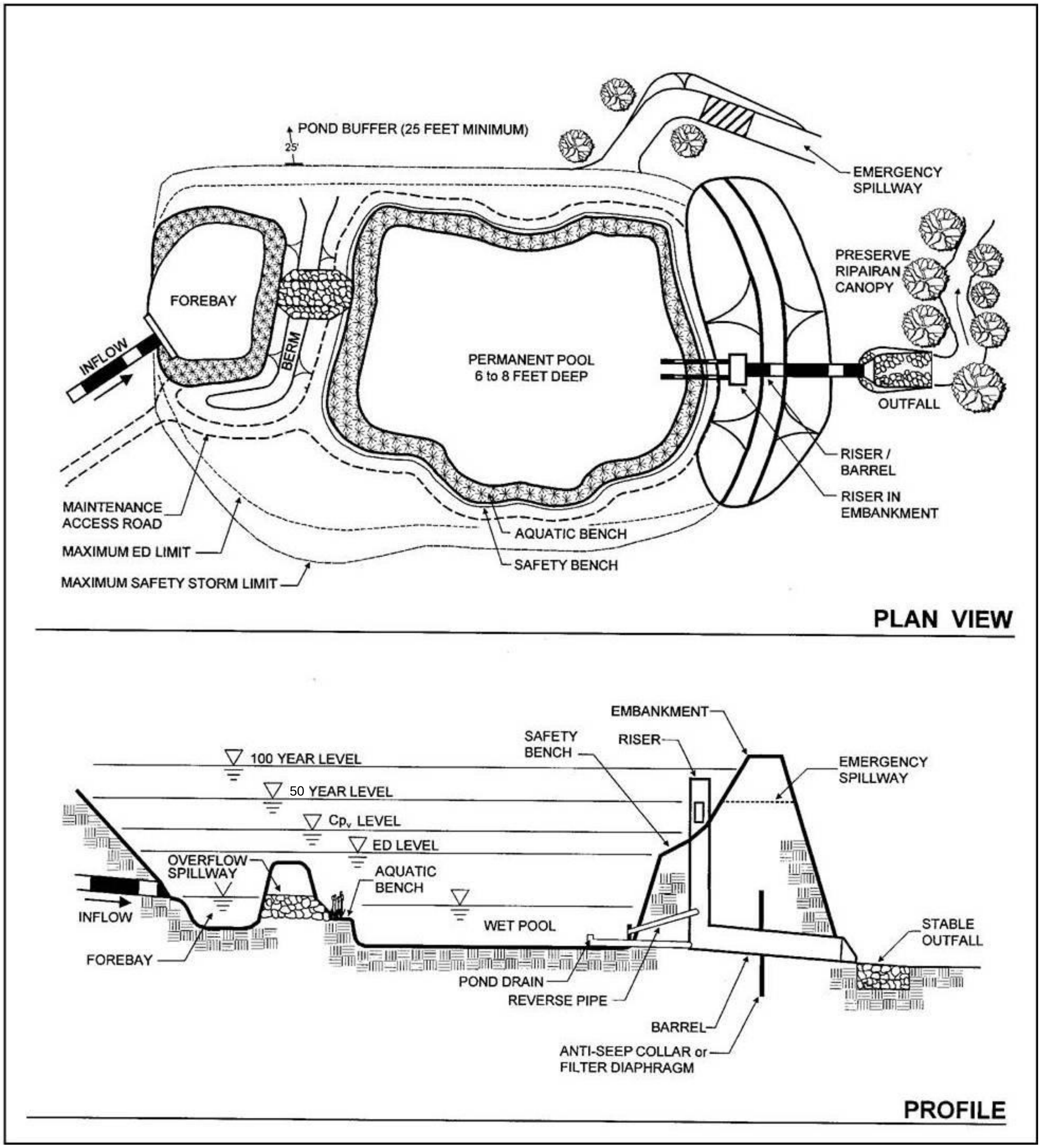


Figure 3.2.1-5 Schematic of Wet Extended Detention Pond

(Source: Center for Watershed Protection)

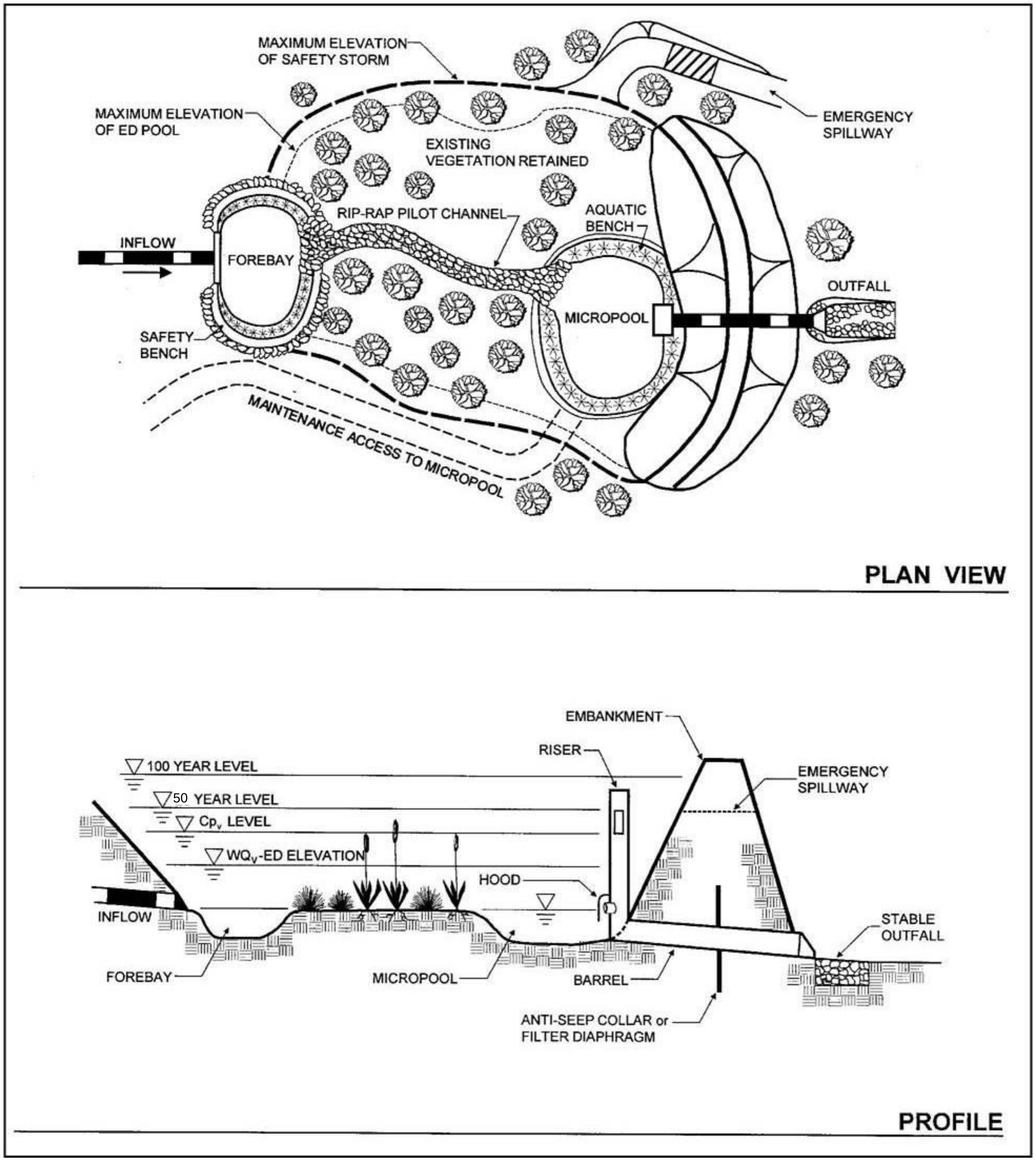


Figure 3.2.1-6 Schematic of Micropool Extended Detention Pond

(Source: Center for Watershed Protection)

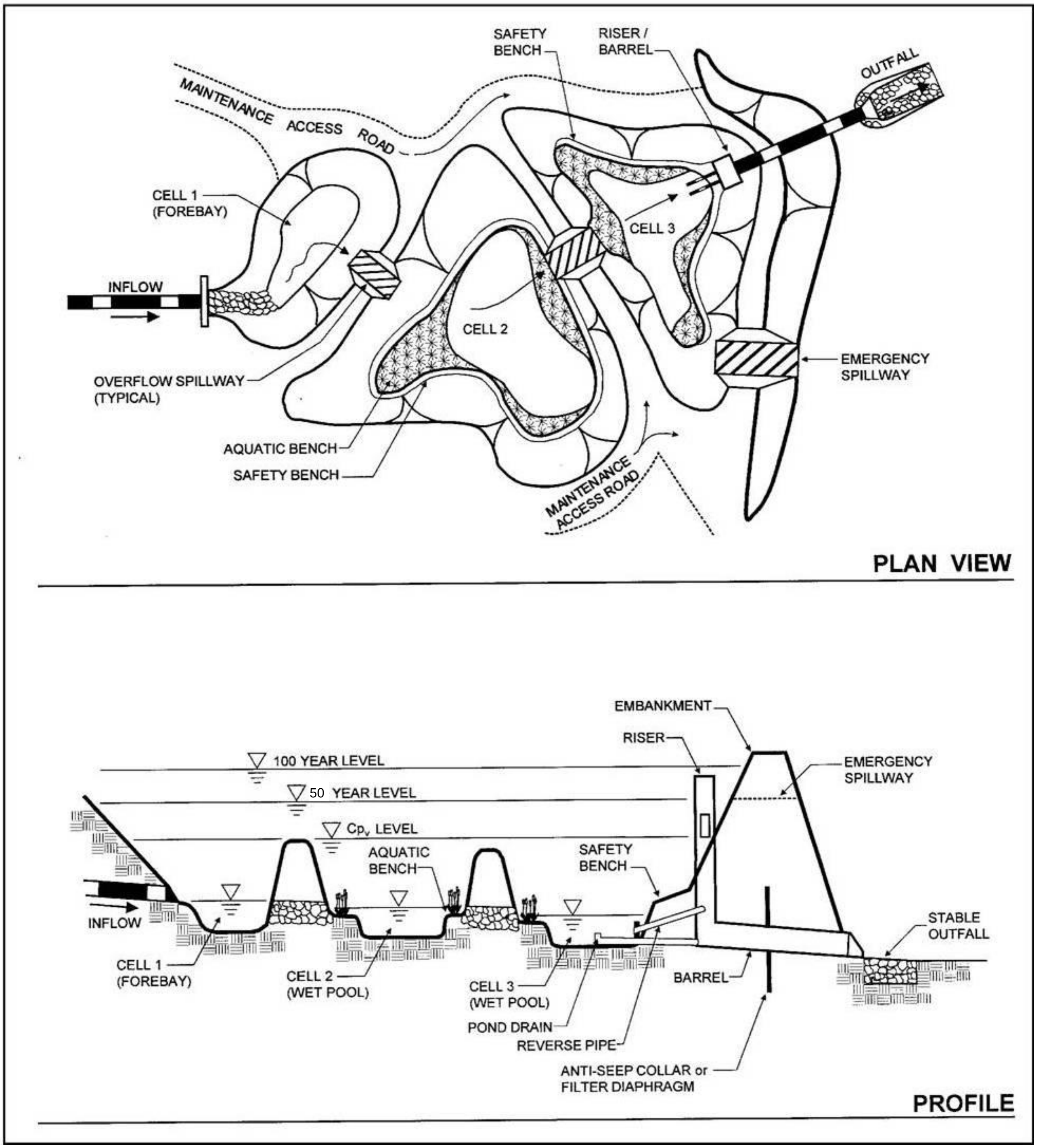


Figure 3.2.1-7 Schematic of Multiple Pond System

(Source: Center for Watershed Protection)

3.2.1.9 Design Forms

Design Procedure Form: Stormwater Ponds

PRELIMINARY HYDROLOGIC CALCULATIONS

1a) Compute WQ_v volume requirements
Compute Runoff Coefficient, R_v — R_v = ________
Compute WQ_v — WQ_v = ________ acre - ft

1b) Compute Cp_v — Cp_v = ________ acre - ft
Compute average release rate — release rate = ________ cfs
Compute Q_{p50} — Q_{p50} = ________ acre - ft
Add 15% to the required Q_{p50} volume — Q_{p50} * 15% = ________ acre - ft
Compute (as necessary) Q_f — Q_f = ________ acre - ft

STORMWATER POND DESIGN

2) Is the use of a stormwater pond appropriate? — **See subsections 3.2.1.4 and 3.2.1.5-A**

3) Confirm local design criteria and applicability

4) Pretreatment volume — Vol_{pre} = ________ acre - ft
Vol_{pre} = I (0.1")(1'/12")

5) Allocation of Permanent Pool Volume and ED Volume
Wet Pond: $Vol_{pool} = WQ_v$ — Vol_{pool} = ________ acre - ft

Wet ED Pond: $Vol_{pool} = 0.5(WQ_v)$ — Vol_{pool} = ________ acre - ft
$Vol_{ED} = 0.5(WQ_v)$ — Vol_{ED} = ________ acre - ft

Micropool ED Pond: $Vol_{pool} = 0.25(WQ_v)$ — Vol_{pool} = ________ acre - ft
$Vol_{ED} = 0.75(WQ_v)$ — Vol_{ED} = ________ acre - ft

6) Conduct grading and determine storage available for permanent pool (and WQ_v-ED volume, if applicable) — *Prepare an elevation - storage table and curve using the average area method for computing*

Elevation MSL	Area ft^2	Average Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3	Cumulative Volume ac-ft	Volume Above Permanent Pool ac-ft

7) WQ_v Orifice Computations
Average ED release rate (if applicable) — release rate = ________ cfs
Average head, h = (ED elev - Permanent pool elev.) / 2 — h = ________ ft
Area of orifice from orifice equation
$Q = CA (2gh)^{0.5}$ — A = ________ ft^2
diameter = ________ in
Discharge equation $Q = (h)^{\wedge 0.5}$ — factor = ________ $(h)^{\wedge 0.5}$

Compute release rate for Cp_v-ED control and establish Cp_v elevation — WSEL = ________ ft - NGVD
Release rate = — release rate = ________ cfs
Average head, h = (Cp_v elev. - Permanent pool elev.) / 2 — h = ________ ft - NGVD
Area of orifice from orifice equation — A = ________ ft^2
$Q = CA (2gh)^{0.5}$ — diameter = ________ in
Discharge equation $Q = (h)^{\wedge 0.5}$ — factor = ________ $(h)^{\wedge 0.5}$

8) Calculate Q_{p50} release rate and WSEL | *Set up a stage-storage-discharge relationship*

Elevation	Storage	Low Flow	Riser				Barrel		Emergency	Total
		WQ_v-ED	Cp_v-ED	High Storage			Inlet	Pipe	Spillway	Storage
				Orif.	Weir					
MSL	ac-ft	H (ft) Q (cfs)	H (ft) Q (cfs)	H Q	H Q		H (ft) Q (cfs)	H (ft) Q (cfs)	H (ft) Q (cfs)	Q (cfs)

Q_{p50} = pre-dev. Peak discharge - (WQ_v-ED release + Cp_v-ED release)

Q_{p50} = ________ cfs

Maximum head =

H = ________ ft

Use weir equation for slot length ($Q = CLH^{3/2}$)

L = ________ ft

Check inlet condition

Check outlet condition

Use culvert charts (Section 4.3)

9) Size emergency spillway, calculate 100-year WSEL and set top of embankment elevation

$WSEL_{50}$ = ________ ft

$WSEL_{100}$ = ________ ft

Q_{ES} = ________ cfs

Q_{PS} = ________ cfs

10) Investigate potential pond hazard classification

See Appendix H

11) Design inlets, sediment forebays, outlet structures, maintenance access, and safety features.

See subsection 3.2.1.5 - D through H

12) Attach landscaping plan

See Appendix F

Notes: ______________________________

____

____

____

3.2.2 Stormwater Wetlands

Description: Constructed wetland systems used for stormwater management. Runoff volume is both stored and treated in the wetland facility.

KEY CONSIDERATIONS

DESIGN CRITERIA:

- Minimum contributing drainage area of 25 acres; 5 acres for pocket wetland
- Minimum dry weather flow path of 2:1 (length:width) should be provided from inflow to outflow
- Minimum of 35% of total surface area should have a depth of 6 inches or less; 10 to 20% of surface area should be deep pool (1.5- to 6-foot depth

ADVANTAGES / BENEFITS:

- Good nutrient removal
- Provides natural wildlife habitat
- Relatively low maintenance costs

DISADVANTAGES / LIMITATIONS:

- Requires large land area
- Needs continuous baseflow for viable wetland
- Sediment regulation is critical to sustain wetlands

MAINTENANCE REQUIREMENTS:

- Replace wetland vegetation to maintain at least 50% surface area coverage
- Remove invasive vegetation
- Monitor sediment accumulation and remove periodically

POLLUTANT REMOVAL

80%	**Total Suspended Solids**
40 / 30%	**Nutrients –** Total Phosphorus / Total Nitrogen removal
50%	**Metals** – Cadmium, Copper, Lead, and Zinc removal
70%	**Pathogens** – Coliform, Streptococci, E.Coli removal

STORMWATER MANAGEMENT SUITABILITY

- ☑ **Water Quality**
- ☑ **Channel Protection**
- ☑ **Overbank Flood Protection**
- ☑ **Extreme Flood Protection**

Accepts Hotspot Runoff: *Yes*

(2 feet of separation distance required to water table)

FEASIBILITY CONSIDERATIONS

M - H	**Land Requirement**
M	**Capital Cost**
	Maintenance Burden
M	Shallow Wetland
M	ED Shallow Wetland
H	Pocket Wetland
M	Pond / Wetland

Residential Subdivision Use: *Yes*

High Density / Ultra – Urban: *No*

Drainage Area: *25 acres min.*

Soils: *Hydrologic group ‘A’ and ‘B’ soils may require pond liner*

L=Low **M**=Moderate **H**=High

3.2.2.1 General Description

Stormwater wetlands (also referred to as *constructed wetlands*) are constructed shallow marsh systems that are designed to both treat urban stormwater and control runoff volumes. As stormwater runoff flows through the wetland facility, pollutant removal is achieved through settling and uptake by marsh vegetation.

Wetlands are among the most effective stormwater practices in terms of pollutant removal and also offer aesthetic value and wildlife habitat. Constructed stormwater wetlands differ from natural wetland systems in that they are engineered facilities designed specifically for the purpose of treating stormwater runoff and typically have less biodiversity than natural wetlands both in terms of plant and animal life. However, as with natural wetlands, stormwater wetlands require a continuous base flow or a high water table to support aquatic vegetation.

There are several design variations of the stormwater wetland, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland. These include the shallow wetland, the extended detention shallow wetland, pond/wetland system and pocket wetland. Below are descriptions of each design variant:

- **Shallow Wetland** – In the shallow wetland design, most of the water quality treatment volume is in the relatively shallow high marsh or low marsh depths. The only deep portions of the shallow wetland design are the forebay at the inlet to the wetland, and the micropool at the outlet. One disadvantage of this design is that, since the pool is very shallow, a relatively large amount of land is typically needed to store the water quality volume.
- **Extended Detention (ED) Shallow Wetland** – The extended detention (ED) shallow wetland design is the same as the shallow wetland; however, part of the water quality treatment volume is provided as extended detention above the surface of the marsh and released over a period of 24 hours. This design can treat a greater volume of stormwater in a smaller space than the shallow wetland design. In the extended detention wetland option, plants that can tolerate both wet and dry periods need to be specified in the ED zone.
- **Pond/Wetland Systems** – The pond/wetland system has two separate cells: a wet pond and a shallow marsh. The wet pond traps sediments and reduces runoff velocities prior to entry into the wetland, where stormwater flows receive additional treatment. Less land is required for a pond/wetland system than for the shallow wetland or the ED shallow wetland systems.
- **Pocket Wetland** – A pocket wetland is intended for smaller drainage areas of 5 to 10 acres and typically requires excavation down to the water table for a reliable water source to support the wetland system.

> Certain types of wetlands, such as *submerged gravel wetland systems* are not recommended for general application use to meet stormwater management goals due to limited performance data. They may be applicable in special or retrofit situations where there are severe limitations on what can be implemented. Please see a further discussion in Section 3.3.5.

3.2.2.2 Stormwater Management Suitability

Similar to stormwater ponds, stormwater wetlands are designed to control both stormwater quantity and quality. Thus, a stormwater wetland can be used to address all of the *unified stormwater sizing criteria* for a given drainage area.

<u>Water Quality</u>

Pollutants are removed from stormwater runoff in a wetland through uptake by wetland vegetation and algae, vegetative filtering, and through gravitational settling in the slow moving marsh flow. Other pollutant removal mechanisms are also at work in a stormwater wetland, including chemical and biological decomposition, and volatilization. Section 3.2.2.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

Shallow Wetland

Shallow ED Wetland

Newly Constructed Shallow Wetland

Pocket Wetland

Figure 3.2.2-1 Stormwater Wetland Examples

<u>Channel Protection</u>

The storage volume above the permanent pool/water surface level in a stormwater wetland is used to provide control of the channel protection volume (Cp_v). This is accomplished by releasing the 2-year, 24-hour storm runoff volume over 24 hours (extended detention). It is best to do this with minimum vertical water level fluctuation, as extreme fluctuation may stress vegetation.

<u>Overbank Flood Protection</u>

A stormwater wetland can also provide storage above the permanent pool/water surface level to reduce the post-development peak flow of the 50-year storm (Q_p) to pre-development levels (detention). If a wetland facility is not used for overbank flood protection, it should be designed as an off-line system to pass higher flows around rather than through the wetland system.

<u>Extreme Flood Protection</u>

In situations where it is required, stormwater wetlands can also be used to provide detention to control the 100-year storm peak flow (Q_f). Where Q_f peak control is not required, a stormwater wetland must be designed to safely pass extreme storm flows.

3.2.2.3 Pollutant Removal Capabilities

All of the stormwater wetland design variants are presumed to be able to remove 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed wetland facilities can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or “treatment train” approach.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – 40%**
- **Total Nitrogen – 30%**
- **Fecal Coliform – 70% (if no resident waterfowl population present)**
- **Heavy Metals – 50%**

3.2.2.4 Application and Site Feasibility Criteria

Stormwater wetlands are generally applicable to most types of new development and redevelopment, and can be utilized in both residential and nonresidential areas. However, due to the large land requirements, wetlands may not be practical in higher density areas. The following criteria should be evaluated to ensure the suitability of a stormwater wetland for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage – YES
- Suitable for High Density/Ultra Urban Areas – Land requirements may preclude use
- Regional Stormwater Control – YES

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – A minimum of 25 acres and a positive water balance is needed to maintain wetland conditions; 5 acres for pocket wetland
- Space Required – Approximately 3 to 5% of the tributary drainage area
- Site Slope – There should be no more than 8% slope across the wetland site
- Minimum Head – Elevation difference needed at a site from the inflow to the outflow: 3 to 5 feet; 2 to 3 feet for pocket wetland
- Minimum Depth to Water Table – If used on a site with an underlying water supply aquifer or when treating a hotspot, a separation distance of 2 feet is recommended between the bottom of the wetland and the elevation of the seasonally high water table; pocket wetland is typically below water table.
- Soils – Permeable soils are not well suited for a constructed stormwater wetland without a high water table. Underlying soils of hydrologic group “C” or “D” should be adequate to maintain wetland conditions. Most group “A” soils and some group “B” soils will require a liner. *Evaluation of soils should be based upon an actual subsurface analysis and permeability tests*.

3.2.2.5 Planning and Design Criteria

*The following criteria are to be considered **minimum** standards for the design of a stormwater wetland facility. Consult with Columbia County to determine if there are any variations to these criteria or additional standards that must be followed.*

A. LOCATION AND SITING

- Stormwater wetlands should normally have a minimum contributing drainage area of 25 acres or more. For a pocket wetland, the minimum drainage area is 5 acres.
- A continuous base flow or high water table is required to support wetland vegetation. A water balance must be performed to demonstrate that a stormwater wetland can withstand a 30-day drought at summer evaporation rates without completely drawing down (see subsection 2.1.8 for details).

- Wetland siting should also take into account the location and use of other site features such as natural depressions, buffers, and undisturbed natural areas, and should attempt to aesthetically "fit" the facility into the landscape. Bedrock close to the surface may prevent excavation.
- Stormwater wetlands cannot be located within navigable waters of the U.S., including wetlands, without obtaining a Section 404 permit under the Clean Water Act, and any other applicable State permit. In some isolated cases, a wetlands permit may be granted to convert an existing degraded wetland in the context of local watershed restoration efforts.
- If a wetland facility is not used for overbank flood protection, it should be designed as an off-line system to bypass higher flows rather than passing them through the wetland system.
- Minimum setback requirements for stormwater wetland facilities (when not specified by local ordinance or criteria):
    - From a property line – 10 feet
    - From a private well – 100 feet; if well is down-gradient from a hotspot land use, then the minimum setback is 250 feet
    - From a septic system tank/leach field – 50 feet
- All utilities should be located outside of the wetland site.

B. GENERAL DESIGN

- A well-designed stormwater wetland consists of:
    (1) Shallow marsh areas of varying depths with wetland vegetation,

    (2) Permanent micropool, and

    (3) Overlying zone in which runoff control volumes are stored.

    Pond/wetland systems also include a stormwater pond facility (see Section 3.2.1, *Stormwater Ponds*, for pond design information).
- In addition, **all wetland designs must include a sediment forebay at the inflow** to the facility to allow heavier sediments to drop out of suspension before the runoff enters the wetland marsh. (Design information for sediment forebays can be found in Appendix B)
- Additional pond design features include an **emergency spillway, maintenance access, safety bench, wetland buffer, and appropriate wetland vegetation and native landscaping**.

Figures 3.2.2-3 through 3.2.2-6 in subsection 3.2.2.8 provide plan view and profile schematics for the design of a shallow wetland, ED shallow wetland, pond/wetland system, and pocket wetland.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

In general, wetland designs are unique for each site and application. However, there are number of geometric ratios and limiting depths for the design of a stormwater wetland that must be observed for adequate pollutant removal, ease of maintenance, and improved safety. Table 3.2.2-1 provides the recommended physical specifications and geometry for the various stormwater wetland design variants.

- The stormwater wetland should be designed with the recommended proportion of "depth zones." Each of the four wetland design variants has depth zone allocations which are given as a percentage of the stormwater wetland surface area. Target allocations are found in Table 3.2.2-1. The four basic depth zones are:

    Deepwater zone

    From 1.5 to 6 feet deep. Includes the outlet micropool and deepwater channels through the wetland facility. This zone supports little emergent wetland vegetation, but may support submerged or floating vegetation.

    Low marsh zone

    From 6 to 18 inches below the normal permanent pool or water surface elevation. This zone is suitable for the growth of several emergent wetland plant species.

High marsh zone

From 6 inches below the pool to the normal pool elevation. This zone will support a greater density and diversity of wetland species than the low marsh zone. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone.

Semi-wet zone

Those areas above the permanent pool that are inundated during larger storm events. This zone supports a number of species that can survive flooding.

Design Criteria	Shallow Wetland	ED Shallow Wetland	Pond/ Wetland	Pocket Wetland
Length to Width Ratio (minimum)	2:1	2:1	2:1	2:1
Extended Detention (ED)	No	Yes	Optional	Optional
Allocation of WQ_v Volume (pool / marsh / ED) in %	25 / 75 / 0	25 / 25 / 50	70 / 30 / 0 (includes pond volume)	25 / 75 / 0
Allocation of Surface Area (deepwater / low marsh / high marsh / semi-wet) in %	20 / 35 / 40 / 5	10 / 35 / 45 / 10	45 / 25 / 25 / 5 (includes pond surface area)	10 / 45 / 40 / 5
Forebay	Required	Required	Required	Optional
Micropool	Required	Required	Required	Required
Outlet Configuration	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir	Hooded broad-crested weir

Depth

Deepwater: 1.5 to 6 feet below normal pool elevation

Low Marsh: 6 to 18 inches below normal pool elevation

High Marsh: 6 inches or less below normal pool elevation

Semi-Wet Zone: Above normal pool elevation.

Table 3.2.2-1 Recommended Design Criteria for Stormwater Wetlands

Modified from Massachusetts DEP, 1997; Schueler, 1992

- A minimum dry weather flow path of 2:1 (length to width) is required from inflow to outlet across the stormwater wetland and should ideally be greater than 3:1. This path may be achieved by constructing internal dikes or berms, using marsh plantings, and by using multiple cells. Finger dikes are commonly used in surface flow systems to create serpentine configurations and prevent short-circuiting. Micro-topography (contours along the bottom of a wetland or marsh that provide a variety of conditions for different species needs and increases the surface area to volume ratio) is encouraged to enhance wetland diversity.
- A 4- to 6-foot deep micropool must be included in the design at the outlet to prevent the outlet from clogging and resuspension of sediments, and to mitigate thermal effects.
- Maximum depth of any permanent pool areas should generally not exceed 6 feet.
- The volume of the extended detention must not comprise more than 50% of the total WQ_v, and its maximum water surface elevation must not extend more than 3 feet above the normal pool. Q_p and/or Cp_v storage can be provided above the maximum WQ_v elevation within the wetland.
- The perimeter of all deep pool areas (4 feet or greater in depth) should be surrounded by safety and aquatic benches similar to those for stormwater ponds (see subsection 3.2.1).
- The contours of the wetland should be irregular to provide a more natural landscaping effect.

D. PRETREATMENT / INLETS

- Sediment regulation is critical to sustain stormwater wetlands. A wetland facility should have a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal into the wetland. The forebay should consist of a separate cell, formed by an acceptable barrier. A forebay is to be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the wetland facility.
- The forebay is sized to contain 0.1 inches per impervious acre of contributing drainage and should be 4 to 6 feet deep. The pretreatment storage volume is part of the total WQ_v requirement and may be subtracted from WQ_v for wetland storage sizing.
- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels are to be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the pond can be partially submerged. Exit velocities from the forebay must be non-erosive.

E. OUTLET STRUCTURES

- Flow control from a stormwater wetland is typically accomplished with the use of a concrete or corrugated metal riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base of the micropool with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment (see Figure 3.2.2-2). The riser should be located within the embankment for maintenance access, safety and aesthetics.
- A number of outlets at varying depths in the riser provide internal flow control for routing of the water quality, channel protection, and overbank flood protection runoff volumes. The number of orifices can vary and is usually a function of the pond design.

  For shallow and pocket wetlands, the riser configuration is typically comprised of a channel protection outlet (usually an orifice) and overbank flood protection outlet (often a slot or weir). The channel protection orifice is sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some cold water streams). Since the water quality volume is fully contained in the permanent pool, no orifice sizing is necessary for this volume. As runoff from a water quality event enters the wet pond, it simply displaces that same volume through the channel protection orifice. Thus an off-line shallow or pocket wetland providing *only* water quality treatment can use a simple overflow weir as the outlet structure.

  In the case of an extended detention (ED) shallow wetland, there is generally a need for an additional outlet (usually an orifice) that is sized to pass the extended detention water quality volume that is surcharged on top of the permanent pool. Flow will first pass through this orifice, which is sized to release the water quality ED volume in 24 hours. The preferred design is a reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the pond. The next outlet is sized for the release of the channel protection storage volume. The outlet (often an orifice) invert is located at the maximum elevation associated with the extended detention water quality volume and is sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some cold water streams).

  Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested rectangular, V-notch, proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool.

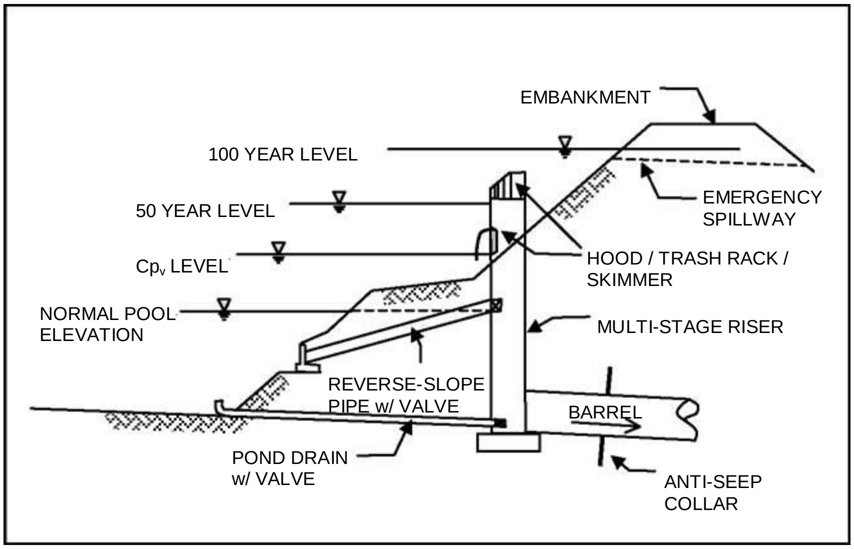


Figure 3.2.2-2 Typical Wetland Facility Outlet Structure

- The water quality outlet (if design is for an ED shallow wetland) and channel protection outlet should be fitted with adjustable gate valves or other mechanism that can be used to adjust detention time.
- Higher flows (overbank and extreme flood protection) flows pass through openings or slots protected by trash racks further up on the riser.
- After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars should be installed on the outlet barrel to reduce the potential for pipe failure.
- Riprap, plunge pools or pads, or other energy dissipators are to be placed at the outlet of the barrel to prevent scouring and erosion. If a wetland facility daylights to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. See Section 4.5 (*Energy Dissipation Design*) for more guidance.
- The wetland facility must have a bottom drain pipe located in the micropool with an adjustable valve that can completely or partially dewater the wetland within 24 hours. *(This requirement may be waived for areas, where positive drainage is difficult to achieve due to very low relief.)*
- The wetland drain should be sized one pipe size greater than the calculated design diameter. The drain valve is typically a hand-wheel activated knife or gate valve. Valve controls shall be located inside of the riser at a point where they (a) will not normally be inundated and (b) can be operated in a safe manner.

See the design procedures in subsection 3.2.2.6 as well as Section 2.2 (*Storage Design*) and Section 2.3 (*Outlet Structures*) for additional information and specifications on pond routing and outlet works.

F. EMERGENCY SPILLWAY

- An emergency spillway is to be included in the stormwater wetland design to safely pass flows that exceed the design storm flows. The spillway prevents the wetland's water levels from overtopping the embankment and causing structural damage. The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.
- A minimum of 1 foot of freeboard must be provided, measured from the top of the water surface elevation for the extreme flood to the lowest point of the dam embankment, not counting the emergency spillway.

G. MAINTENANCE ACCESS

- A maintenance right of way or easement at least 20 feet wide must be provided to the wetland facility from a public or private road. Maintenance access should be at least 16 feet wide, having a maximum slope of no more than 15%, and be appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access must extend to the forebay, safety bench, riser, and outlet and, to the extent feasible, be designed to allow vehicles to turn around.
- Access to the riser is to be provided by lockable manhole covers, and manhole steps within easy reach of valves and other controls.

H. SAFETY FEATURES

- All embankments and spillways must be designed to State of Georgia guidelines for dam safety.
- Fencing of wetlands is not generally desirable, but will be evaluated by Columbia County on a case-by-case basis. A preferred method is to manage the contours of deep pool areas through the inclusion of a safety bench (see above) to eliminate drop-offs and reduce the potential for accidental drowning.
- The principal spillway opening should not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent a hazard.

I. LANDSCAPING

- A landscaping plan should be provided that indicates the methods used to establish and maintain wetland coverage. Minimum elements of a plan include: delineation of landscaping zones, selection of corresponding plant species, planting plan, sequence for preparing wetland bed (including soil amendments, if needed) and sources of plant material.
- Landscaping zones include low marsh, high marsh, and semi-wet zones. The low marsh zone ranges from 6 to 18 inches below the normal pool. This zone is suitable for the growth of several emergent plant species. The high marsh zone ranges from 6 inches below the pool up to the normal pool. This zone will support greater density and diversity of emergent wetland plant species. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone. The semi-wet zone refers to those areas above the permanent pool that are inundated on an irregular basis and can be expected to support wetland plants.
- The landscaping plan should provide elements that promote greater wildlife and waterfowl use within the wetland and buffers.
- Woody vegetation may not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- A wetland buffer shall extend 25 feet outward from the maximum water surface elevation, with an additional 15-foot setback to structures. The wetland buffer should be contiguous with other buffer areas that are required by existing regulations (e.g., stream buffers) or that are part of the overall stormwater management concept plan. No structures should be located within the buffer, and an additional setback to permanent structures may be provided.
- Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To discourage resident geese populations, the buffer can be planted with trees, shrubs and native ground covers.
- The soils of a wetland buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration and therefore may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites and backfill these with uncompacted topsoil.

Guidance on establishing wetland vegetation can be found in Appendix F (*Landscaping and Aesthetics Guidance)*.

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Providing wetland drain can be problematic
- High Relief – Embankment heights restricted
- Karst – Requires poly or clay liner to sustain a permanent pool of water and protect aquifers; limits on ponding depth; geotechnical tests may be required

Soils

- Hydrologic group "A' soils and some group "B' soils may require liner (not relevant for pocket wetland)

Special Downstream Watershed Considerations

- Aquifer Protection – Prevent possible groundwater contamination by preventing infiltration of hotspot runoff. May require liner for type "A' soils; Pretreat hotspots; 2 to 4 foot separation distance from water table.
- Swimming Area/Shellfish – Design for geese prevention (see Appendix F); Provide 48-hour ED for maximum Coliform die-off.

3.2.2.6 Design Procedures

Step 1: Compute runoff control volumes from the Unified Stormwater Sizing Criteria.

A. Calculate the Water Quality Volume (WQ_v), Channel Protection Volume (Cp_v), Overbank Flood Protection Volume (Q_p), and the Extreme Flood Volume (Q_f).

B. Details on the Unified Stormwater Sizing Criteria are found in Section 1.3.

Step 2: Determine if the development site and conditions are appropriate for the use of a stormwater wetland.

A. Consider the Application and Site Feasibility Criteria in subsections 3.2.2.4 and 3.2.2.5-A (Location and Siting).

Step 3: Confirm Columbia County's design criteria and applicability.

A. Consider any special site-specific design conditions/criteria from subsection 3.2.2.5-J. (Additional Site-Specific Design Criteria and Issues).

B. Check with Columbia County officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4: Determine pretreatment volume.

A. A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond. The forebay should be sized to contain 0.1 inches per impervious acre of contributing drainage and should be 4 to 6 feet deep. The forebay storage volume counts toward the total WQ_v requirement and may be subtracted from the WQ_v for subsequent calculations.

Step 5: Allocate the WQ_v volume among marsh, micropool, and ED volumes.

A. Use recommended criteria from Table 3.2.2-1.

Step 6: Determine wetland location and preliminary geometry, including distribution of wetland depth zones.

A. This step involves initially laying out the wetland design and determining the distribution of wetland surface area among the various depth zones (high marsh, low marsh, and deepwater). Set WQ_v permanent pool elevation (and WQ_v-ED elevation for ED shallow wetland) based on volumes calculated earlier.

B. See subsection 3.2.2.5-C (Physical Specification / Geometry) for more details.

Step 7: Compute extended detention orifice release rate(s) and size(s), and establish Cp_v elevation.

A. *Shallow Wetland and Pocket Wetland:* The Cp_v elevation is determined from the stage-storage relationship and the orifice is then sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some cold water streams). The channel protection orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. A reverse lope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool is a recommended design. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (i.e., an over-perforated vertical stand pipe with ½–inch orifices or slots that are protected by wirecloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter.

B. *ED Shallow Wetland:* Based on the elevations established in Step 6 for the extended detention portion of the water quality volume, the water quality orifice is sized to release this extended detention volume in 24 hours. The water quality orifice should have a minimum diameter of 3 inches, and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged one foot below the elevation of permanent pool, is a recommended design. Adjustable ate valves can also be used to achieve this equivalent diameter. The Cp_v elevation is then determined from the stage-storage relationship. The invert of the channel protection orifice is located at the water quality extended detention elevation, and the orifice is sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some cold water streams).

Step 8: Calculate Q_{p50} (50-year storm) release rate and water surface elevation.

A. Set up a stage-storage-discharge relationship for the control structure for the extended detention orifice(s) and the 50-year storm.

Step 9: Design embankment(s) and spillway(s).

A. Size emergency spillway, calculate 100-year water surface elevation, set top of embankment elevation, and analyze safe passage of the Extreme Flood Volume (Q_f).

B. At final design, provide safe passage for the 100-year event. Attenuation may not be required.

Step 10: Investigate potential pond/wetland hazard classifications.

A. The design and construction of stormwater management ponds and wetlands are required to follow the latest version of the State of Georgia dam safety rules.

Step 11: Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

A. See subsection 3.2.2.5-D through H for more details.

Step 12: Prepare Vegetation and Landscaping Plan.

A. A landscaping plan for the wetland facility and its buffer should be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation.

B. See subsection 3.2.2.5-I (Landscaping) and Appendix F for more details.

3.2.2.7 Inspection and Maintenance Requirements

Activity	Schedule
• Replace wetland vegetation to maintain at least 50% surface area coverage in wetland plants after the second growing season.	One-Time Activity
• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Frequently (3 to 4 times/year)
• Monitor wetland vegetation and perform replacement planting as necessary.	Semi-annual Inspection (first 3 years)
• Examine stability of the original depth zones and micro-topographical features. • Inspect for invasive vegetation, and remove where possible. • Inspect for damage to the embankment and inlet/outlet structures. • Repair as necessary. • Note signs of hydrocarbon build-up, and remove appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational.	Annual Inspection
• Repair undercut or eroded areas.	As Needed
• Harvest wetland plants that have been “choked out” by sediment build-up.	Annually
• Removal of sediment from the forebay.	5 to 7 years or after 50% of the total forebay capacity has been lost
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, plants are "choked" with sediment, or the wetland becomes eutrophic.	10 to 20 years or after 25% of the wetland volume has been lost

Table 3.2.2-2 Typical Maintenance Activities for Wetlands
(Adapted from WMI, 1997 and CWP, 1998)

Additional Maintenance Considerations and Requirements

- Maintenance requirements for constructed wetlands are particularly high while vegetation is being established. Monitoring during these first years is crucial to the future success of the wetland as a stormwater structural control. Wetland facilities should be inspected after major storms (greater than 2 inches of rainfall) during the first year of establishment to assess bank stability, erosion damage, flow channelization, and sediment accumulation within the wetland. For the first 3 years, inspections should be conducted at least twice a year.
- A sediment marker should be located in the forebay to determine when sediment removal is required.
- Accumulated sediments will gradually decrease wetland storage and performance. The effects of sediment deposition can be mitigated by the removal of the sediments.
- Sediments excavated from stormwater wetlands that do not receive runoff from designated hotspots are not considered toxic or hazardous material and can be safely disposed of by either land application or landfilling. Sediment testing may be required prior to sediment disposal when a hotspot land use is present. Sediment removed from stormwater wetlands should be disposed of according to an approved erosion and sediment control plan.
- Periodic mowing of the wetland buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest.

Regular inspection and maintenance is critical to the effective operation of stormwater wetlands as designed. Maintenance responsibility for this BMP should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval. **Columbia County will not accept ownership of or maintain this type of BMP.**

3.2.2.8 Example Schematics

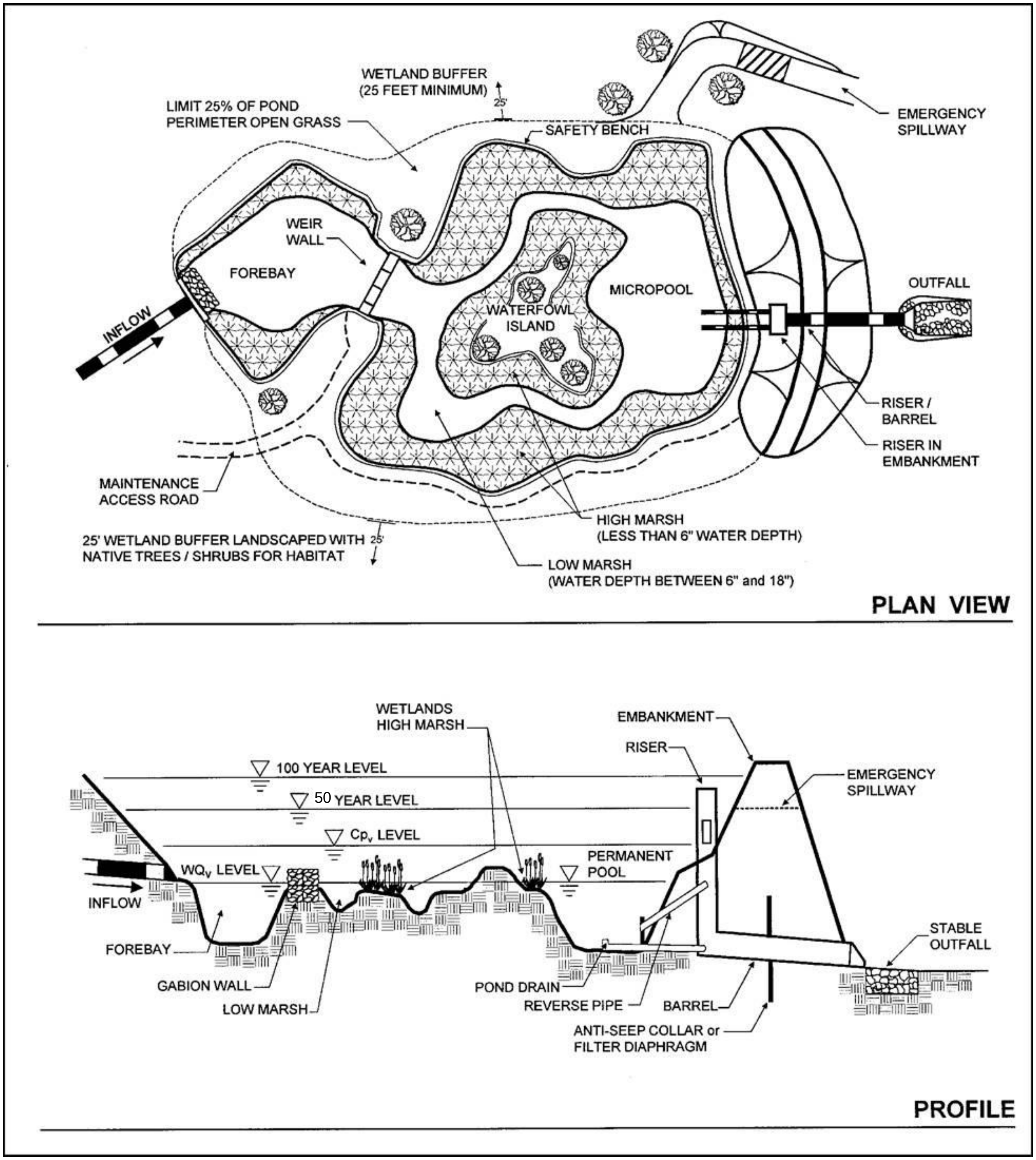


Figure 3.2.2-3 Schematic of Shallow Wetland

(Source: Center for Watershed Protection)

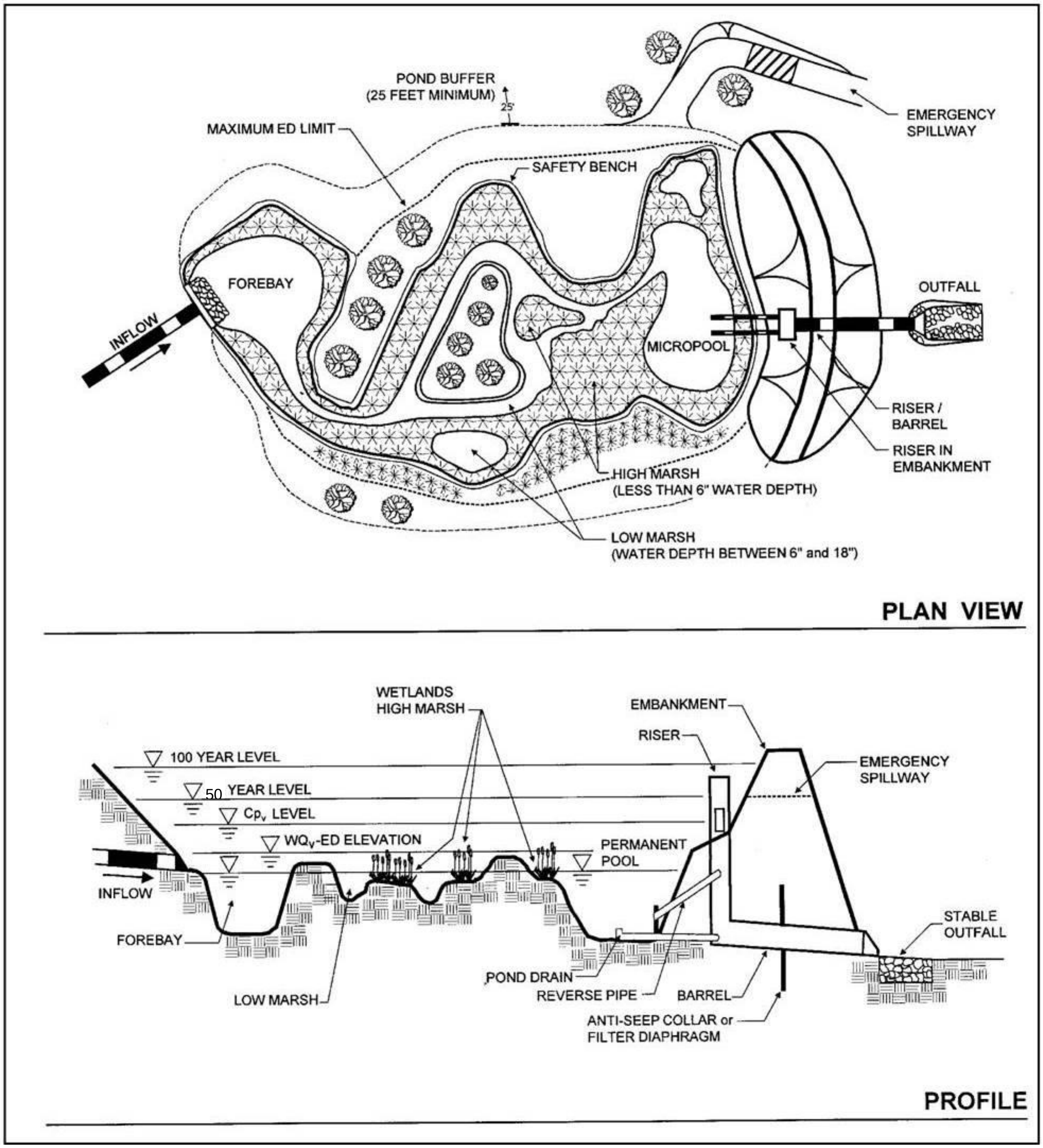


Figure 3.2.2-4 Schematic of Extended Detention Shallow Wetland

(Source: Center for Watershed Protection)

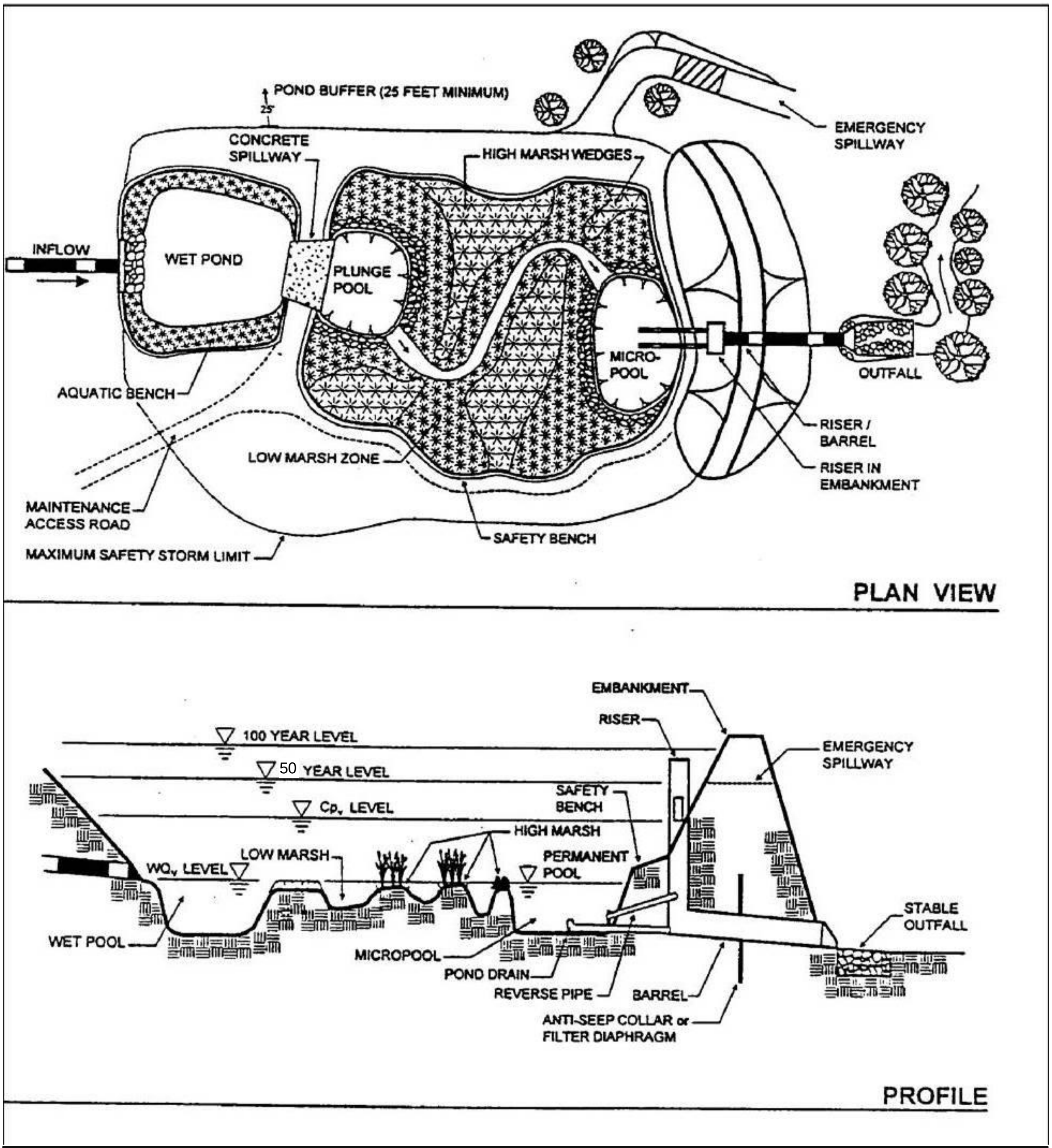


Figure 3.2.2-5 Schematic of Pond / Wetland System

(Source: Center for Watershed Protection)

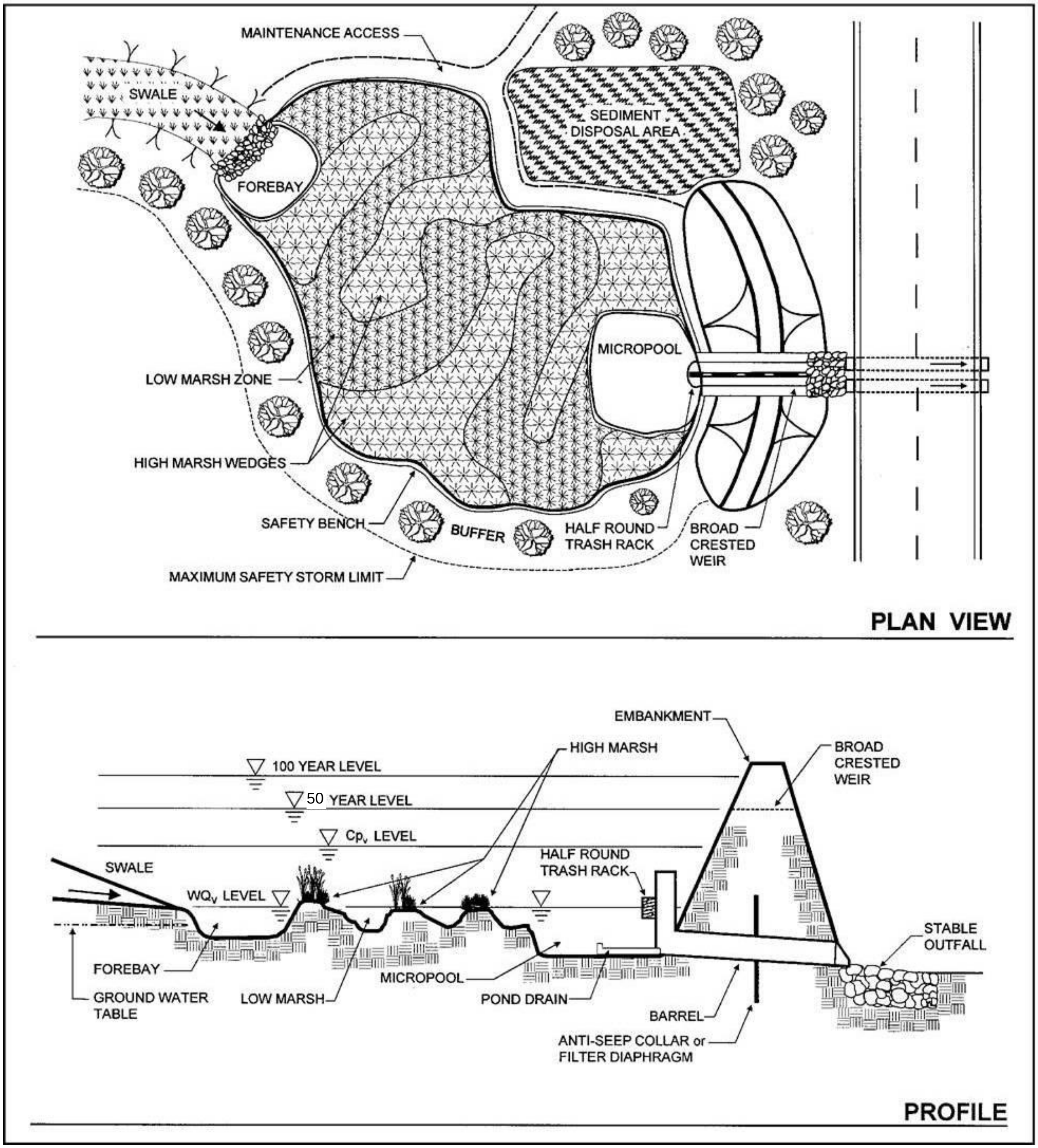


Figure 3.2.2-6 Schematic of Pocket Wetland

(Source: Center for Watershed Protection)

3.2.2.9 Design Forms

Design Procedure Form: Stormwater Wetlands

PRELIMINARY HYDROLOGIC CALCULATIONS

1a) Compute WQ_v volume requirements

Compute Runoff Coefficient, R_v — R_v = ________

Compute WQ_v — WQ_v = ________ acre - ft

1b) Compute Cp_v — Cp_v = ________ acre - ft

Compute average release rate — release rate = ________ cfs

Compute Q_{p50} — Q_{p50} = ________ acre - ft

Add 15% to the required Q_{p50} volume — Q_{p50} * 15% = ________ acre - ft

Compute (as necessary) Q_f — Q_f = ________ acre - ft

STORMWATER WETLAND DESIGN

2) Is the use of a stormwater wetland appropriate? — **See subsections 3.2.2.4 and 3.2.2.5-A**

3) Confirm local design criteria and applicability

4) Pretreatment volume — Vol_{pre} = ________ acre - ft

Vol_{pre} = I (0.1")(1'/12")

5) Allocation of Permanent Pool Volume and ED Volum

Shallow Wetla Vol_{pool} = 0.2 (WQ_v) — Vol_{pool} = ________ acre - ft

Vol_{marsh} = 0.7 (WQ_v) — Vol_{marsh} = ________ acre - ft

Shallow ED W Vol_{pool} = 0.1 (WQ_v) — Vol_{pool} = ________ acre - ft

Vol_{marsh} = 0.3 (WQ_v) — Vol_{marsh} = ________ acre - ft

Vol_{ED} = 0.5 (WQ_v) — Vol_{ED} = ________ acre - ft

Pocket Wetla Vol_{pool} = 0.1 (WQ_v) — Vol_{pool} = ________ acre - ft

Vol_{marsh} = 0.8 (WQ_v) — Vol_{marsh} = ________ acre - ft

6) Allocation of Surface Area

Pool / Deepwater Wetland Zone (1.5 - 6 feet deep) — $Area_{water}$ = ________ acres, %= ________

Low Marsh Wetland Zone (6 - 18 inches deep) — $Area_{low}$ = ________ acres, %= ________

High Marsh Wetland Zone (0 - 6 inches deep) — $Area_{high}$ = ________ acres, %= ________

Semi-Wet Wetland Zone (above pool depth) — $Area_{semi}$ = ________ acres, %= ________

100.00%

Conduct grading and determine storage available for marsh zones (and ED if applicable), and compute orifice size

Prepare an elevation - storage table and curve using the average area method for computing volumes.

Elevation MSL	Area ft^2	Average Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3	Cumulative Volume ac-ft	Volume Above Permanent Pool ac-ft

7) WQ_v Orifice Computations

Average ED release rate (if applicable)	release rate = ______	cfs
Average head, h = (ED elev - Permanent pool elev.) / 2	h = ______	ft
Area of orifice from orifice equation		
$Q = CA\,(2gh)^{0.5}$	A = ______	ft^2
	diameter = ______	in
Discharge equation $Q = (h)^{\wedge 0.5}$	factor = ______	$(h)^{\wedge 0.5}$
Compute release rate for Cp_v-ED control and establish Cp_v elevation	WSEL = ______	ft - NGVD
Release rate =	release rate = ______	cfs
Average head, h = (Cp_v elev. - Permanent pool elev.) / 2	h = ______	ft
Area of orifice from orifice equation	A = ______	ft^2
$Q = CA\,(2gh)^{0.5}$	diameter = ______	in
Discharge equation $Q = (h)^{\wedge 0.5}$	factor = ______	$(h)^{\wedge 0.5}$

8) Calculate Q_{p50} release rate and WSEL

Set up a stage-storage-discharge relationship

Elevation	Storage	Low Flow	Riser			Barrel		Emergency	Total
		WQ_v-ED	Cp_v-ED	High Storage		Inlet	Pipe	Spillway	Storage
				Orif.	Weir				
MSL	ac-ft	H (ft) Q (cfs)	H (ft) Q (cfs)	H Q	H Q	H (ft) Q (cfs)	H (ft) Q (cfs)	H (ft) Q (cfs)	Q (cfs)

Q_{p50} = pre-dev. Peak discharge - (WQ_v - ED release + Cp_v - ED release)	Q_{p50} = ______	cfs
Maximum head =	H = ______	ft
Use weir equation for slot length ($Q = CLH^{3/2}$)	L = ______	ft
Check inlet condition	***Use culvert charts***	
Check outlet condition	***(Section 4.3)***	
9) Size emergency spillway, calculate 100-year WSEL and set	$WSEL_{50}$ = ______	ft
	$WSEL_{100}$ = ______	ft
	Q_{ES} = ______	cfs
	Q_{PS} = ______	cfs
10) Investigate potential pond hazard classification	***See Appendix H***	
11) Design inlets, sediment forebays, outlet structures, maintenance access, and safety features.	***See subsection 3.2.2.5 - D through H***	
12) Attach landscaping plan (including wetland vegetation)	***See Appendix F***	

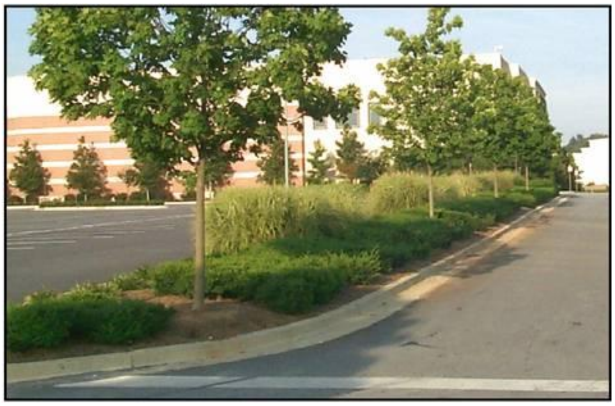
Notes: ______________________________

____

____

____

3.2.3 Bioretention Areas



Description: Shallow stormwater basin or landscaped area that utilizes engineered soils and vegetation to capture and treat runoff.

KEY CONSIDERATIONS

DESIGN CRITERIA:

- Maximum contributing drainage area of 5 acres
- Often located in "landscaping islands"
- Treatment area consists of grass filter, sand bed, ponding area, organic / mulch layer, planting soil, and vegetation
- Typically requires 5 feet of head

ADVANTAGES / BENEFITS:

- Applicable to small drainage areas
- Good for highly impervious surface areas, particularly parking lots
- Good retrofit capability
- Relatively low maintenance requirements
- Can be planned as an aesthetic feature

DISADVANTAGES / LIMITATIONS:

- Requires extensive landscaping
- Not recommended for areas with steep slopes

MAINTENANCE REQUIREMENTS:

- Inspect and repair / replace treatment area components

POLLUTANT REMOVAL

80%	**Total Suspended Solids**
60 / 50%	**Nutrients –** Total Phosphorus / Total Nitrogen removal
80%	**Metals** – Cadmium, Copper, Lead, and Zinc removal
No data	**Pathogens** – Coliform, Streptococci, E.Coli removal

STORMWATER MANAGEMENT SUITABILITY

☑ **Water Quality**

✪ **Channel Protection**

☐ **Overbank Flood Protection**

☐ **Extreme Flood Protection**

Accepts Hotspot Runoff: *Yes (requires impermeable liner)*

✪ in certain situations

IMPLEMENTATION CONSIDERATIONS

M	**Land Requirement**
M	**Capital Cost**
L	**Maintenance Burden**

Residential Subdivision Use: *Yes*

High Density / Ultra – Urban: *Yes*

Drainage Area: *5 acres max.*

Soils: *Planting soils must meet specified criteria; No restrictions on surrounding soils*

Other Considerations:

- *Use of native plants is recommended*

L=Low **M**=Moderate **H**=High

3.2.3.1 General Description

Bioretention areas (also referred to as *bioretention filters* or *rain gardens*) are structural stormwater controls that capture and temporarily store the water quality volume (WQ_v) using soils and vegetation in shallow basins or landscaped areas to remove pollutants from stormwater runoff.

Bioretention areas are engineered facilities in which runoff is conveyed as sheet flow to the "treatment area," which consists of a grass buffer strip, ponding area, organic or mulch layer, planting soil, and vegetation. An optional sand bed can also be included in the design to provide aeration and drainage of the planting soil. The filtered runoff is typically collected and returned to the conveyance system, though it can also be exfiltrated into the surrounding soil in areas with porous soils.

There are numerous design applications, both on- and off-line, for bioretention areas. These include use on single-family residential lots (*rain gardens*), as off-line facilities adjacent to parking lots, along highway and road drainage swales, within larger landscaped pervious areas, and as landscaped islands in impervious or high-density environments. Figures 3.2.3-1 and 3.2.3-2 illustrate a number of examples of bioretention facilities in both photographs and drawings.

Single – Family Residential "Rain Garden"

Landscaped Island

Newly Constructed Bioretention Area

Newly Planted Bioretention Area after Storm

Figure 3.2.3-1 Bioretention Area Examples

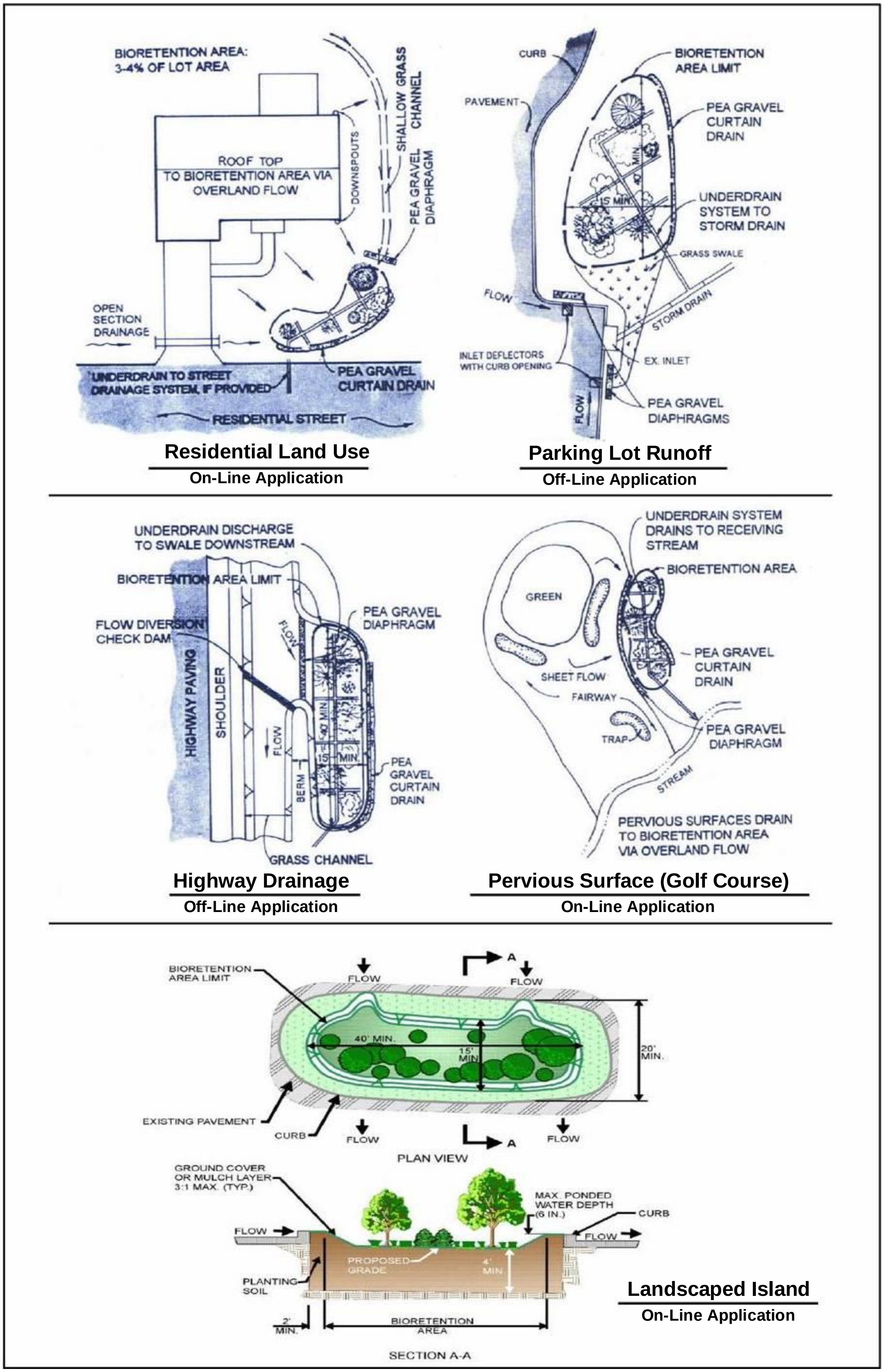


Figure 3.2.3-2 Bioretention Area Applications
(Source: Claytor and Schueler, 1996)

3.2.3.2 Stormwater Management Suitability

Bioretention areas are designed primarily for stormwater quality, i.e. the removal of stormwater pollutants. Bioretention can provide limited runoff quantity control, particularly for smaller storm events. These facilities may sometimes be used to partially or completely meet channel protection requirements on smaller sites. However, bioretention areas will typically need to be used in conjunction with another structural control to provide channel protection as well as overbank flood protection. It is important to ensure that a bioretention area safely bypasses higher flows.

<u>Water Quality</u>

Bioretention is an excellent stormwater treatment practice due to the variety of pollutant removal mechanisms. Each of the components of the bioretention area is designed to perform a specific function (see Figure 3.2.3-3). The *grass filter strip (or grass channel)* reduces incoming runoff velocity and filters particulates from the runoff. The *ponding area* provides for temporary storage of stormwater runoff prior to its evaporation, infiltration, or uptake and provides additional settling capacity. The *organic or mulch layer* provides filtration as well as an environment conducive to the growth of microorganisms that degrade hydrocarbons and organic material. The *planting soil* in the bioretention facility acts as a filtration system, and clay in the soil provides adsorption sites for hydrocarbons, heavy metals, nutrients and other pollutants. Both *woody and herbaceous plants* in the ponding area provide vegetative uptake of runoff and pollutants and also serve to stabilize the surrounding soils. Finally, a *sand bed* provides for positive drainage and aerobic conditions in the planting soil and provides a final polishing treatment media.

Section 3.2.3.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

<u>Channel Protection</u>

For smaller sites, a bioretention area may be designed to capture the entire channel protection volume Cp_v in either an off- or on-line configuration. Given that a bioretention facility is typically designed to completely drain over 48 hours, the requirement of extended detention of the 2-year, 24-hour storm runoff volume will be met. For larger sites –or– where only the WQ_v is diverted to the bioretention facility, another structural control must be used to provide Cp_v extended detention.

<u>Overbank Flood Protection</u>

Another structural control must be used in conjunction with a bioretention area to reduce the post-development peak flow of the 50-year storm (Q_{p50}) to pre-development levels (detention).

<u>Extreme Flood Protection</u>

Bioretention areas must provide flow diversion and/or be designed to safely pass extreme storm flows and protect the ponding area, mulch layer and vegetation.

Credit for the volume of runoff removed and treated in the bioretention area may be taken in the overbank flood protection and extreme flood protection calculations (see Section 3.1).

3.2.3.3 Pollutant Removal Capabilities

Bioretention areas are presumed to be able to remove 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed bioretention areas can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or “treatment train” approach.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – 60%**
- **Total Nitrogen – 50%**
- **Fecal Coliform – insufficient data**
- **Heavy Metals – 80%**

3.2.3.4 Application and Site Feasibility Criteria

Bioretention areas are suitable for many types of development, from single-family residential to high-density commercial projects. Bioretention is also well suited for small lots, including those of 1 acre or less. Because of its ability to be incorporated in landscaped areas, the use of bioretention is extremely flexible. Bioretention areas are an ideal structural stormwater control for use as roadway median strips and parking lot islands and are also good candidates for the treatment of runoff from pervious areas, such as a golf course. Bioretention can also be used to retrofit existing development with stormwater quality treatment capacity.

The following criteria should be evaluated to ensure the suitability of a bioretention area for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage – YES
- Suitable for High Density/Ultra Urban Areas – YES
- Regional Stormwater Control – NO

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 5 acres maximum; 0.5 to 2 acres are preferred.
- Space Required – Approximately 5% of the tributary impervious area is required; minimum 200 ft^2 area for small sites (10 feet x 20 feet)
- Site Slope – No more than 6% slope
- Minimum Head – Elevation difference needed at a site from the inflow to the outflow: 5 feet
- Minimum Depth to Water Table – A separation distance of 2 feet recommended between the bottom of the bioretention facility and the elevation of the seasonally high water table.
- Soils – No restrictions; engineered media required

Other Constraints / Considerations

- Aquifer Protection – Do not allow exfiltration of filtered hotspot runoff into groundwater

3.2.3.5 Planning and Design Criteria

*The following criteria are to be considered **minimum** standards for the design of a bioretention facility.*

A. LOCATION AND SITING

Bioretention areas should have a maximum contributing drainage area of 5 acres or less; 0.5 to 2 acres are preferred. Multiple bioretention areas can be used for larger areas.

- Bioretention areas can either be used to capture sheet flow from a drainage area or function as an off-line device. On-line designs should be limited to a maximum drainage area of 0.5 acres.
- When used in an off-line configuration, the water quality volume (WQ_v) is diverted to the bioretention area through the use of a flow splitter. Stormwater flows greater than the WQ_v are diverted to other controls or downstream (see Section 3.1 for more discussion of off-line systems and design guidance for diversion structures and flow splitters).
- Bioretention systems are designed for intermittent flow and must be allowed to drain and reaerate between rainfall events. They should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.
- Bioretention area locations should be integrated into the site planning process, and aesthetic considerations should be taken into account in their siting and design. Elevations must be carefully worked out to ensure that the desired runoff flow enters the facility with no more than the maximum design depth.

B. GENERAL DESIGN

- A well-designed bioretention area consists of:
  - **(1) Grass filter strip (or grass channel) between the contributing drainage area and the ponding area,**
  - **(2) Ponding area containing vegetation with a planting soil bed,**
  - **(3) Organic/mulch layer, and**
  - **(4) Gravel and perforated pipe underdrain system to collect runoff that has filtered through the soil layers (bioretention areas can optionally be designed to infiltrate into the soil – see description of infiltration trenches for infiltration criteria).**
- A bioretention area design will also include some of the following:
  - Optional **sand filter layer** to spread flow, filter runoff, and aid in aeration and drainage of the planting soil.
  - **Stone diaphragm** at the beginning of the grass filter strip to reduce runoff velocities and spread flow into the grass filter.
  - **Inflow diversion** or an **overflow structure** consisting of one of five main methods:
    - Use a flow diversion structure
    - For curbed pavements use an inlet deflector (see Figure 3.2.3-6).
    - Use a slotted curb and design the parking lot grades to divert the WQ_v into the facility. Bypass additional runoff to a downstream catch basin inlet. Requires temporary ponding in the parking lot (see Figure 3.2.3-5).
    - Figure 3.2.3-2c illustrates the use of a short deflector weir (maximum height 6 inches) designed to divert the maximum water quality peak flow into the bioretention area.
    - An in-system overflow consisting of an overflow catch basin inlet and/or a pea gravel curtain drain overflow.

See Figure 3.2.3-3 for an overview of the various components of a bioretention area. Figure 3.2.3-4 provides a plan view and profile schematic of an on-line bioretention area. An example of an off-line facility is shown in Figure 3.2.3-5.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- Recommended minimum dimensions of a bioretention area are 10 feet wide by 20 feet long. All designs except small residential applications should maintain a length to width ratio of at least 2:1.
- The planting soil filter bed is sized using a Darcy's Law equation with a filter bed drain time of 48 hours and a coefficient of permeability (k) of 0.5 ft/day.
- The maximum recommended ponding depth of the bioretention areas is 6 inches.
- The planting soil bed must be at least 4 feet in depth. Planting soils should be sandy loam, loamy sand, or loam texture with a clay content ranging from 10 to 25%. The soil must have an infiltration rate of at least 0.5 inches per hour and a pH between 5.5 and 6.5. In addition, the planting soil should have a 1.5 to 3% organic content and a maximum 500 ppm concentration of soluble salts.
- For on-line configurations, a grass filter strip with a pea gravel diaphragm is typically utilized (see Figure 3.2.3-3) as the pretreatment measure. The required length of the filter strip depends on the drainage area, imperviousness, and the filter strip slope. Design guidance on filter strips for pretreatment can be found in subsection 3.3.1 (*Filter Strip)*.
- For off-line applications, a grass channel with a pea gravel diaphragm flow spreader is used for pretreatment. The length of the grass channel depends on the drainage area, land use, and channel slope. The minimum grassed channel length should be 20 feet. Design guidance on grass channels for pretreatment can be found in subsection 3.3.2 (*Grass Channel)*.
- The mulch layer should consist of 2 to 4 inches of commercially available fine shredded hardwood mulch or shredded hardwood chips.

- The sand bed should be 12 to 18 inches thick. Sand should be clean and have less than 15% silt or clay content.
- Pea gravel for the diaphragm and curtain, where used, should be ASTM D 448 size No. 6 (⅛" to ¼").
- The underdrain collection system is equipped with a 6-inch perforated PVC pipe (AASHTO M 252) in an 8-inch gravel layer. The pipe should have ⅜-inch perforations, spaced at 6-inch centers, with a minimum of 4 holes per row. The pipe is spaced at a maximum of 10 feet on center and a minimum grade of 0.5% must be maintained. A permeable filter fabric is placed between the gravel layer and the planting soil bed.

D. PRETREATMENT / INLETS

- Adequate pretreatment and inlet protection for bioretention systems is provided when all of the following are provided: (a) grass filter strip below a level spreader, or grass channel, (b) pea gravel diaphragm and (c) an organic or mulch layer.

E. OUTLET STRUCTURES

- Outlet pipe is to be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary.

F. EMERGENCY SPILLWAY

- An overflow structure and nonerosive overflow channel must be provided to safely pass flows from the bioretention area that exceeds the storage capacity to a stabilized downstream area or watercourse. If the system is located off-line, the overflow should be set above the shallow ponding limit.
- The high flow overflow system <u>within</u> the structure consists of a yard drain catch-basin (Figure 3.2.3-3), though any number of conventional systems could be used. The throat of the catch basin inlet is normally placed 6 inches above the mulch layer at the elevation of the shallow ponding area.

G. MAINTENANCE ACCESS

- Adequate access must be provided for all bioretention facilities for inspection, maintenance, and landscaping upkeep, including appropriate equipment and vehicles.

H. SAFETY FEATURES

- Bioretention areas generally do not require any special safety features. Fencing of bioretention facilities is not generally desirable.

I. LANDSCAPING

- Landscaping is critical to the performance and function of bioretention areas.
- A dense and vigorous vegetative cover should be established over the contributing pervious drainage areas before runoff can be accepted into the facility.
- The bioretention area should be vegetated to resemble a terrestrial forest ecosystem, with a mature tree canopy, sub-canopy of understory trees, scrub layer, and herbaceous ground cover. Three species each of both trees and scrubs are recommended to be planted.
- The tree-to-shrub ratio should be 2:1 to 3:1. On average, the trees should be spaced 8 feet apart. Plants should be placed at regular intervals to replicate a natural forest. Woody vegetation should not be specified at inflow locations.
- After the trees and shrubs are established, the ground cover and mulch should be established.

- Choose plants based on factors such as whether native or not, resistance to drought and inundation, cost aesthetics, maintenance, etc. Planting recommendations for bioretention facilities are as follows:
  - Native plant species should be specified over non-native species.
  - Vegetation should be selected based on a specified zone of hydric tolerance.
  - A selection of trees with an understory of shrubs and herbaceous materials should be provided.

Additional information and guidance on the appropriate woody and herbaceous species appropriate for bioretention in Georgia, and their planting and establishment, can be found in Appendix F, *Landscaping and Aesthetics Guidance*.

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Use of bioretention areas may be limited by low head
- High Relief – Ponding area surface must be relatively level
- Karst – Use poly-liner or impermeable membrane to seal bottom

Soils

- No restrictions

Special Downstream Watershed Considerations

- Aquifer Protection – No restrictions, if designed with no exfiltration (i.e. outflow to groundwater)

3.2.3.6 Design Procedures

Step 1: Compute runoff control volumes from the Unified Stormwater Sizing Criteria.

A. Calculate the Water Quality Volume (WQ_v), Channel Protection Volume (Cp_v), Overbank Flood Protection Volume (Q_p), and the Extreme Flood Volume (Q_f).

B. Details on the Unified Stormwater Sizing Criteria are found in Section 1.3.

Step 2: Determine if the development site and conditions are appropriate for the use of a stormwater pond.

A. Consider the Application and Site Feasibility Criteria in subsections 3.2.3.4 and 3.2.3.5-A (Location and Siting).

Step 3: Confirm Columbia County's design criteria and applicability.

A. Consider any special site-specific design conditions/criteria from subsection 3.2.3.5-J. (Additional Site-Specific Design Criteria and Issues).

B. Check with Columbia County officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4: Compute WQ_v peak discharge (Q_{wq}).

A. The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see subsection 2.1.7).

(a) Using WQ_v (or total volume to be captured), compute CN

(b) Compute time of concentration using TR-55 method

(c) Determine appropriate unit peak discharge from time of concentration

(d) Compute Q_{wq} from unit peak discharge, drainage area, and WQ_v.

Step 5: Size flow diversion structure, if needed.

A. A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQ_v to the bioretention area.

B. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 6: Determine size of bioretention ponding / filter area.

A. The required planting soil filter bed area is computed using the following equation (based on Darcy's Law):

$$\mathbf{A_f = (WQ_v)(d_f) / [(k)(h_f + d_f)(t_f)]}$$

Where:

A_f = surface area of ponding area (ft^2)

WQ_v = water quality volume (or total volume to be captured)

d_f = filter bed depth
(4 feet minimum)

k = coefficient of permeability of filter media (ft / day)
(use 0.5 ft / day for silt-loam)

h_f = average height of water above filter bed (ft)
(typically 3 inches, which is half of the 6-inch ponding depth)

t_f = design filter bed drain time (days)
(2.0 days or 48 hours is recommended maximum)

Step 7: Set design elevations and dimensions of facility.

A. See subsection 3.2.3.5-C (Physical Specifications / Geometry).

Step 8: Design conveyances to facility (off-line systems).

A. See the example figures to determine the type of conveyances needed for the site.

Step 9: Design pretreatment.

A. Pretreat with a grass filter strip (on-line configuration) or grass channel (off-line), and stone diaphragm.

Step 10: Size underdrain system.

A. See subsection 3.2.3.5-C (Physical Specifications / Geometry).

Step 11: Design emergency overflow.

A. An overflow must be provided to bypass and / or convey larger flows to the downstream drainage system or stabilized watercourse. Nonerosive velocities need to be ensured at the outlet point.

Step 12: Prepare Vegetation and Landscaping Plan.

A. A landscaping plan for the bioretention area should be prepared to indicate how it will be established with vegetation.

B. See subsection 3.2.3.5-I (Landscaping) and Appendix F for more details.

See Appendix D-2 for a Bioretention Area Design Example

3.2.3.7 Inspection and Maintenance Requirements

Activity	Schedule
• Pruning and weeding to maintain appearance. • Mulch replacement when erosion is evident. • Remove trash and debris.	As Needed
• Inspect inflow points for clogging (off-line systems). Remove any sediment. • Inspect filter strip / grass channel for erosion or gullying. Re-seed or sod as necessary. • Trees and shrubs should be inspected to evaluate their health and remove any dead or severely diseased vegetation.	Semi-annually
• The planting soils should be tested for pH to establish acidic levels. If the pH is below 5.2, limestone should be applied. If the pH is above 7.0 to 8.0, then iron sulfate plus sulfur can be added to reduce the pH.	Annually
• Replace mulch over the entire area. • Replace pea gravel diaphragm if warranted.	2 to 3 years

Table 3.2.3-1 Typical Maintenance Activities for Bioretention Areas
(Source: EPA, 1999)

Additional Maintenance Considerations and Requirements

- Maintenance requirements for constructed wetlands are particularly high while vegetation is being established. Monitoring during these first years is crucial to the future success of the wetland as a stormwater structural control. Wetland facilities should be inspected after major storms (greater than 2 inches of rainfall) during the first year of establishment to assess bank stability, erosion damage, flow channelization, and sediment accumulation within the wetland. For the first 3 years, inspections should be conducted at least twice a year.

Regular inspection and maintenance is critical to the effective operation of bioretention facilities as designed. Maintenance responsibility for this BMP should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval. **Columbia County will not accept ownership of or maintain this type of BMP.**

3.2.3.8 Example Schematics

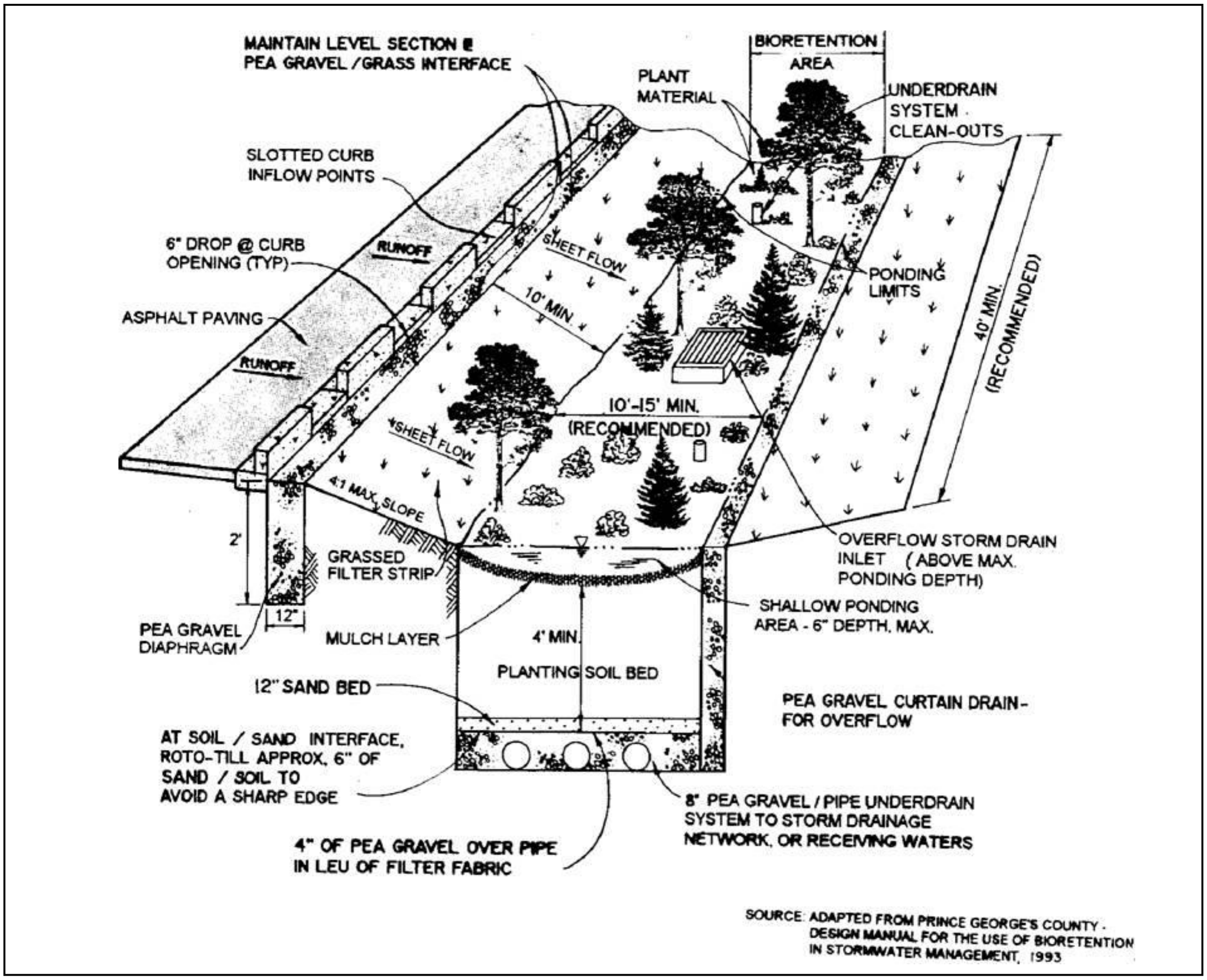


Figure 3.2.3-3 Schematic of a Typical Bioretention Area

(Source: Claytor and Schueler, 1996)

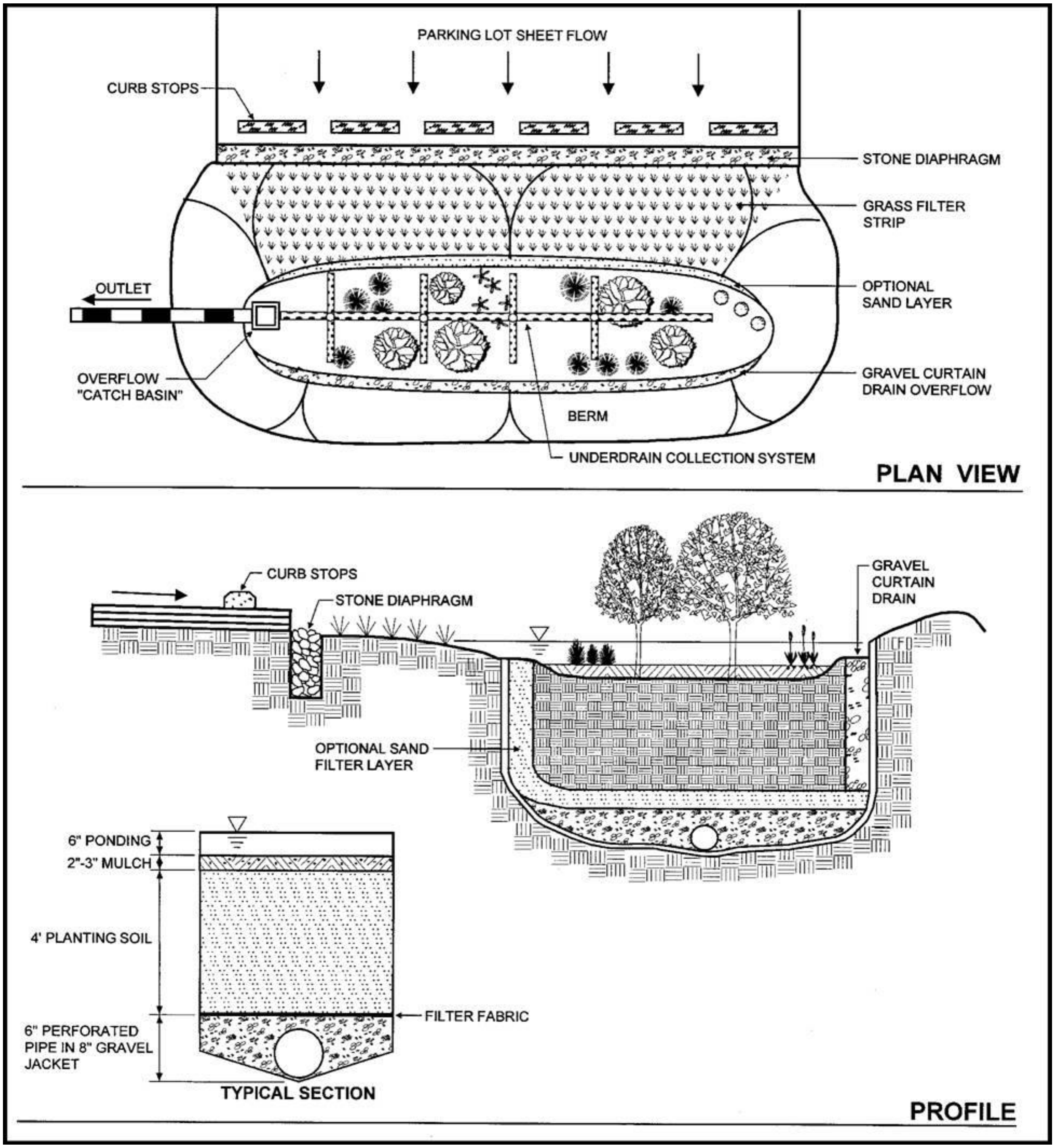


Figure 3.2.3-4 Schematic of a Typical On-Line Bioretention Area

(Source: Claytor and Schueler, 1996)

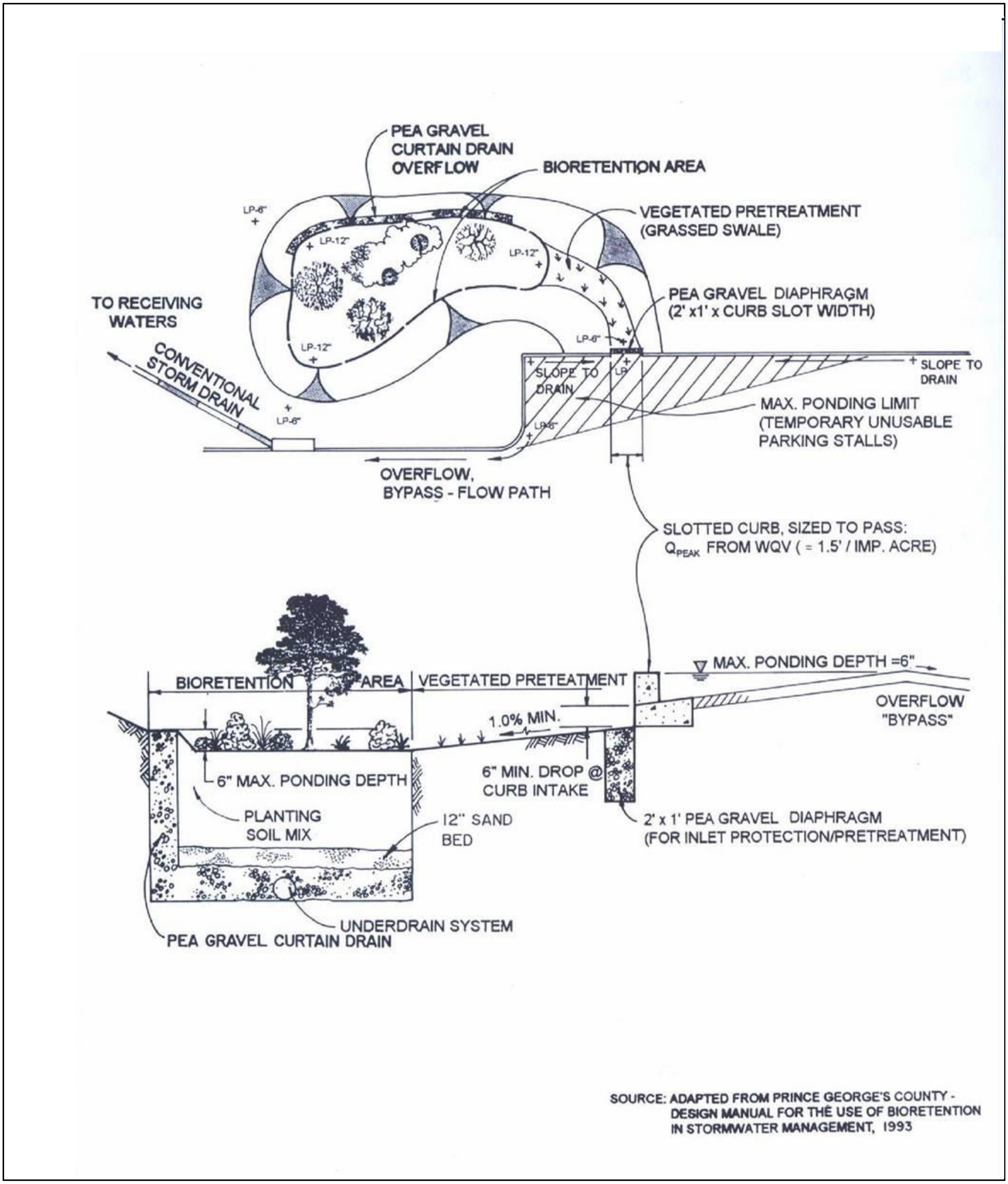


Figure 3.2.3-5 Schematic of a Typical Off-Line Bioretention Area

(Source: Claytor and Schueler, 1996)

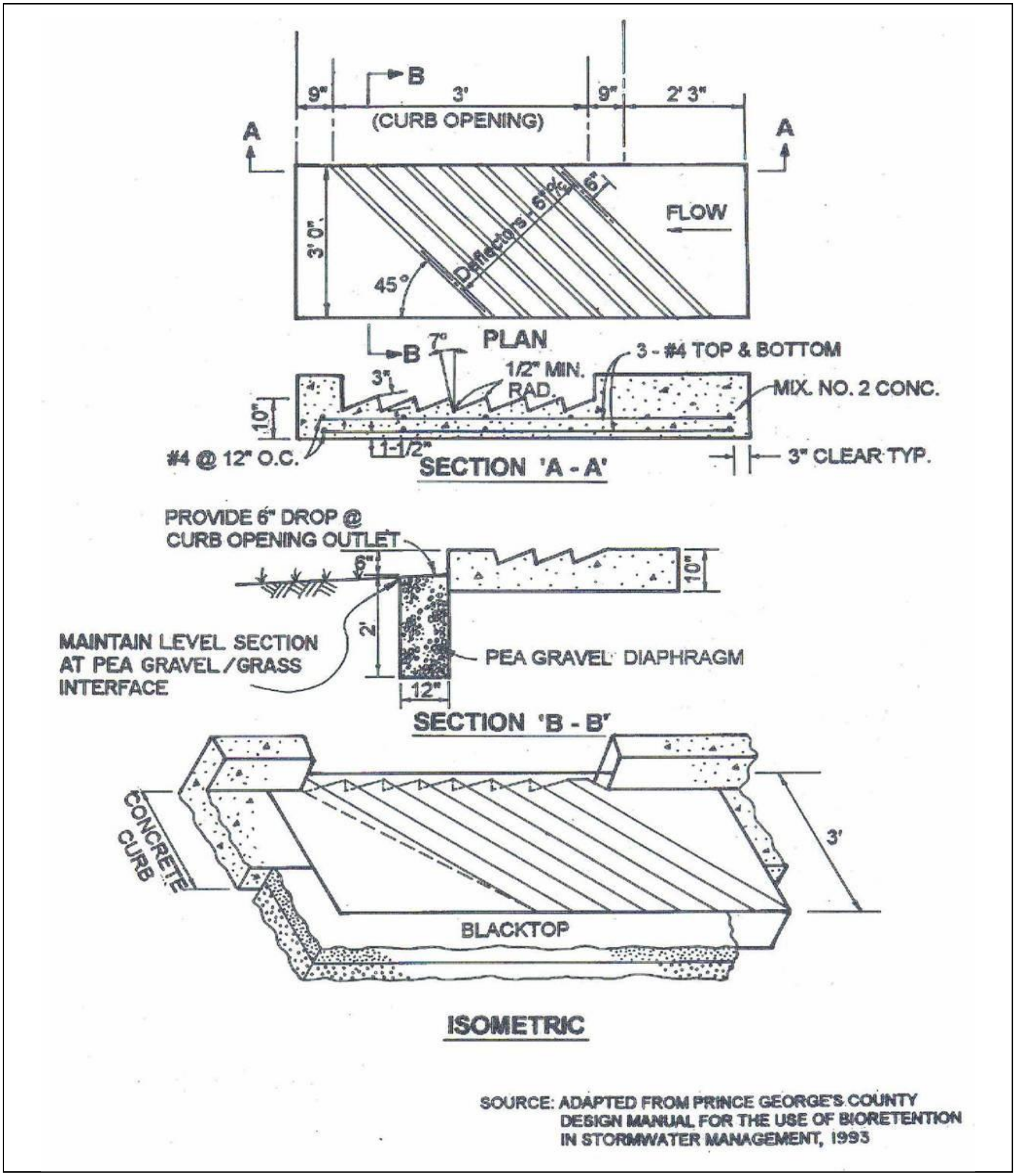


Figure 3.2.3-6 Schematic of a Typical Inlet Deflector

(Source: Claytor and Schueler, 1996)

3.2.3.9 Design Forms

Design Procedure Form: Bioretention Areas

PRELIMINARY HYDROLOGIC CALCULATIO		
1a) Compute WQ_v volume requirements		
Compute Runoff Coefficient, R_v	R_v = ______	
Compute WQ_v	WQ_v = ______	acre - ft
1b) Compute Cp_v	Cp_v = ______	acre - ft
Compute average release rate	release rate = ______	cfs
Compute Q_{p50}	Q_{p50} = ______	acre - ft
Compute (as necessary) Q_f	Q_f = ______	acre - ft
BIORETENTION AREA DESIGN		
2) Is the use of a stormwater pond appropriate?	**See subsections 3.2.3.4 and 3.2.3.5-A**	
3) Confirm local design criteria and applicability		
4) Determine size of bioretention filter area	A_f = ______ ft^2	
5) Set design elevations and dimensions	Length = ______ ft	
	Width = ______ ft	
	______ elevation top of facility	
	______ other elev: ______	
	______ other elev: ______	
	______ other elev: ______	
6) Conveyance to bioretention facility	______ Online or ______ Offline?	
7) Pretreatment	Type: ______	
8) Size underdrain area		
Based on guidance: Approx. 10% A_f	Length = ______ ft	
9) Overdrain design	Type: ______	
	Size: ______	
10) Emergency storm weir design		
Overflow weir - Weir Equation	Length = ______ ft	
11) Choose plants for planting areas	*Select native plants based on resistance to drought and inundation, cost, aesthetics, maintenance, etc.* ***See Appendix F***	

Notes: ______

3.2.4 Sand Filters

General Application
Structural Stormwater Control

Description: Multi-chamber structure designed to treat stormwater runoff through filtration, using a sediment forebay, a sand bed as its primary filter media and, typically, an underdrain collection system.

KEY CONSIDERATIONS

DESIGN CRITERIA:

- Typically requires 2 to 6 feet of head
- Maximum contributing drainage area of 10 acres for surface sand filter; 2 acres for perimeter sand filter.
- Sand filter media with underdrain system

ADVANTAGES / BENEFITS:

- Applicable to small drainage areas
- Good for highly impervious surface areas
- Good retrofit capability

DISADVANTAGES / LIMITATIONS:

- High maintenance burden
- Not recommended for areas with high sediment content in stormwater or clay / silt runoff areas
- Relatively costly
- Possible odor problems

MAINTENANCE REQUIREMENTS:

- Inspect for clogging – rake first inch of sand
- Remove sediment from forebay / chamber
- Replace sand filter media as needed

POLLUTANT REMOVAL

80%	**Total Suspended Solids**
50 / 25%	**Nutrients –** Total Phosphorus / Total Nitrogen removal
50%	**Metals** – Cadmium, Copper, Lead, and Zinc removal
40%	**Pathogens** – Coliform, Streptococci, E.Coli removal

STORMWATER MANAGEMENT SUITABILITY

☑ **Water Quality**

✪ **Channel Protection**

☐ **Overbank Flood Protection**

☐ **Extreme Flood Protection**

Accepts Hotspot Runoff: *Yes (requires impermeable liner)*

✪ in certain situations

IMPLEMENTATION CONSIDERATIONS

L	**Land Requirement**
H	**Capital Cost**
H	**Maintenance Burden**

Residential Subdivision Use: *No*

High Density / Ultra – Urban: *Yes*

Drainage Area: *2-10 acres max.*

Soils: *No restrictions*

Other Considerations:

- Typically needs to be combined with other controls to provide water quantity control

L=Low **M**=Moderate **H**=High

3.2.4.1 General Description

Sand filters (also referred to as *filtration basins*) are structural stormwater controls that capture and temporarily store stormwater runoff and pass it through a filter bed of sand. Most sand filter systems consist of two-chamber structures. The first chamber is a sediment forebay or sedimentation chamber, which removes floatables and heavy sediments. The second is the filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. The filtered runoff is typically collected and returned to the conveyance system, though it can also be partially or fully exfiltrated into the surrounding soil in areas with porous soils.

Because they have few site constraints beside head requirements, sand filters can be used on development sites where the use of other structural controls may be precluded. However, sand filter systems can be relatively expensive to construct and install.

There are two primary sand filter system designs, the *surface sand filter* and the *perimeter sand filter*. Below are descriptions of these filter systems:

- **Surface Sand Filter** – The surface sand filter is a ground-level open air structure that consists of a pretreatment sediment forebay and a filter bed chamber. This system can treat drainage areas up to 10 acres in size and is typically located off-line. Surface sand filters can be designed as an excavation with earthen embankments or as a concrete or block structure.
- **Perimeter Sand Filter** – The perimeter sand filter is an enclosed filter system typically constructed just below grade in a vault along the edge of an impervious area such as a parking lot. The system consists of a sedimentation chamber and a sand bed filter. Runoff flows into the structure through a series of inlet grates located along the top of the control.

A third design variant, the *underground sand filter*, is intended primarily for extremely space limited and high density areas and is thus considered a limited application structural control. See subsection 3.3.4 for more details.

Surface Sand Filter **Perimeter Sand Filter**

Figure 3.2.4-1 Sand Filter Examples

3.2.4.2 Stormwater Management Suitability

Sand filter systems are designed primarily as off-line systems for stormwater quality (i.e., the removal of stormwater pollutants) and will typically need to be used in conjunction with another structural control to provide downstream channel protection, overbank flood protection, and extreme flood protection, if required. However, under certain circumstances, filters can provide limited runoff quantity control, particularly for smaller storm events.

Water Quality

In sand filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration and adsorption. The filtration process effectively removes suspended solids and particulates, Biochemical Oxygen Demand (BOD), Fecal Coliform Bacteria, and other pollutants.

Surface sand filters with a grass cover have additional opportunities for bacterial decomposition as well as vegetation uptake of pollutants, particularly nutrients. Section 3.2.4.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

Channel Protection

For smaller sites, a sand filter may be designed to capture the entire channel protection volume Cp_v in either an off- or on-line configuration. Given that a sand filter system is typically designed to completely drain over 40 hours, the requirement of extended detention of the 1-year, 24-hour storm runoff volume will be met. For larger sites –or– where only the WQ_v is diverted to the sand filter facility, another structural control must be used to provide Cp_v extended detention.

Overbank Flood Protection

Another structural control must be used in conjunction with a sand filter system to reduce the post-development peak flow of the 50-year storm (Q_p) to pre-development levels (detention).

Extreme Flood Protection

Sand filter facilities must provide flow diversion and/or be designed to safely pass extreme storm flows and protect the filter bed and facility.

Credit for the volume of runoff removed and treated by the sand filter may be taken in the overbank flood protection and extreme flood protection calculations (see Section 3.1).

3.2.4.3 Pollutant Removal Capabilities

Both the surface and perimeter sand filters are presumed to be able to remove 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed sand filters can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or “treatment train” approach.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – 60%**
- **Total Nitrogen – 50%**
- **Fecal Coliform – insufficient data**
- **Heavy Metals – 80%**

3.2.4.4 Application and Site Feasibility Criteria

Sand filter systems are well suited for highly impervious areas where land available for structural controls is limited. Sand filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards. Sand filters may also be feasible and appropriate in some multi-family or higher density residential developments.

To avoid rapid clogging and failure of the filter media, the use of sand filters should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of a sand filter facility for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage – NO
- Suitable for High Density/Ultra Urban Areas – YES
- Regional Stormwater Control – NO

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 10 acres maximum for surface sand filter; 2 acres maximum for perimeter sand filter.
- Space Required – Function of available head at site
- Site Slope – No more than 6% slope across filter location
- Minimum Head – Elevation difference needed at a site from the inflow to the outflow: 5 feet for surface sand filters; 2 to 3 feet for perimeter sand filters
- Minimum Depth to Water Table – For a surface sand filter with exfiltration (earthen structure), 2 feet are required between the bottom of the sand filter and the elevation of the seasonally high water table
- Soils – No restrictions; Group "A" soils generally required to allow exfiltration (for surface sand filter earthen structure)

Other Constraints / Considerations

- Aquifer Protection – Do not allow exfiltration of filtered hotspot runoff into groundwater

3.2.4.5 Planning and Design Criteria

*The following criteria are to be considered **minimum** standards for the design of a sand filter facility. Consult with the Columbia County to determine if there are any variations to these criteria or additional standards that must be followed.*

A. LOCATION AND SITING

Surface sand filters should have a contributing drainage area of 10 acres or less. The maximum drainage area for a perimeter sand filter is 2 acres.

Sand filter systems are generally applied to land uses with a high percentage of impervious surfaces. Sites with less than 50% imperviousness or high clay/silt sediment loads must not use a sand filter without adequate pretreatment due to potential clogging and failure of the filter bed. Any disturbed areas within the sand filter facility drainage area should be identified and stabilized. Filtration controls should only be constructed after the construction site is stabilized.

- Surface sand filters are generally used in an off-line configuration where the water quality volume (WQ_v) is diverted to the filter facility through the use of a flow diversion structure and flow splitter. Stormwater flows greater than the WQ_v are diverted to other controls or downstream using a diversion structure or flow splitter.
- Perimeter sand filters are typically sited along the edge, or perimeter, of an impervious area such as a parking lot.
- Sand filter systems are designed for intermittent flow and must be allowed to drain and reaerate between rainfall events. They should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

B. GENERAL DESIGN

Surface Sand Filter

- A surface sand filter facility consists of a two-chamber open-air structure, which is located at ground-level. The first chamber is the sediment forebay (aka sedimentation chamber) while the second chamber houses the sand filter bed. Flow enters the sedimentation chamber where settling of larger sediment particles occurs. Runoff is then discharged from the sedimentation chamber through a perforated standpipe into the filtration chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system. Figure 3.2.4-6 provides plan view and profile schematics of a surface sand filter.

Perimeter Sand Filter

- A perimeter sand filter facility is a vault structure located just below grade level. Runoff enters the device through inlet grates along the top of the structure into the sedimentation chamber. Runoff is discharged from the sedimentation chamber through a weir into the filtration chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system. Figure 3.2.4-7 provides plan view and profile schematics of a perimeter sand filter.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

Surface Sand Filter

- The entire treatment system (including the sedimentation chamber) must temporarily hold at least 75% of the WQ_v prior to filtration. Figure 3.2.4-2 illustrates the distribution of the treatment volume (0.75 WQ_v) among the various components of the surface sand filter, including:
    - V_s – volume within the sedimentation basin
    - V_f – volume within the voids in the filter bed
    - $V_{f\text{-}temp}$ – temporary volume stored above the filter bed
    - A_s – the surface area of the sedimentation basin
    - A_f – surface area of the filter media
    - h_s – height of water in the sedimentation basin
    - h_f – average height of water above the filter media
    - d_f – depth of filter media
- The sedimentation chamber must be sized to at least 25% of the computed WQ_v and have a length-to-width ratio of at least 2:1. Inlet and outlet structures should be located at opposite ends of the chamber.
- The filter area is sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand should be used. The filter bed is typically designed to completely drain in 40 hours or less.
- The filter media consists of an 18-inch layer of clean washed medium sand (meeting ASTM C-33 concrete sand or GADOT Fine Aggregate Size No. 10) on top of the underdrain system. Three inches of topsoil are placed over the sand bed. Permeable filter fabric is placed both above and below the sand bed to prevent clogging of the sand filter and the underdrain system. Figure 3.2.4-4 illustrates a typical media cross section.
- The filter bed is equipped with a 6-inch perforated PVC pipe (AASHTO M 252) underdrain in a gravel layer. The underdrain must have a minimum grade of ⅛-inch per foot (1% slope). Holes should be ⅜-inch diameter and spaced approximately 6 inches on center. Gravel should be clean washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40% (GADOT No.3 Stone). Aggregate contaminated with soil shall not be used.
- The structure of the surface sand filter may be constructed of impermeable media such as concrete, or through the use of excavations and earthen embankments. When constructed with earthen walls/embankments, filter fabric should be used to line the bottom and side slopes of the structures before installation of the underdrain system and filter media.

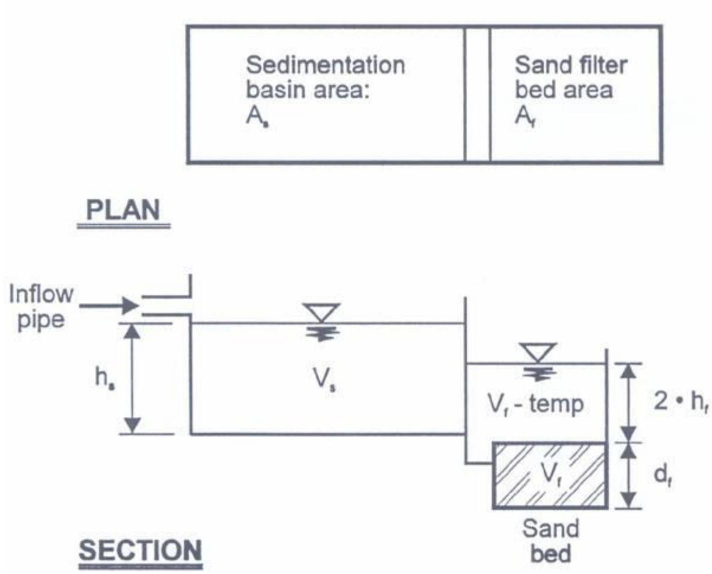


Figure 3.2.4-2 Surface Sand Filter Volumes

Source: Claytor and Schueler, 1996

Perimeter Sand Filter

- The entire treatment system (including the sedimentation chamber) must temporarily hold at least 75% of the WQ_v prior to filtration. Figure 3.2.4-3 illustrates the distribution of the treatment volume (0.75 WQ_v) among the various components of the perimeter sand filter, including:
  - V_w – wet pool volume within the sedimentation basin
  - V_f – volume within the voids in the filter bed
  - V_{temp} – temporary volume stored above the filter bed
  - A_s – the surface area of the sedimentation basin
  - A_f – surface area of the filter media
  - h_f – average height of water above the filter media (½ h_{temp})
  - d_f – depth of filter media
- The sedimentation chamber must be sized to at least 50% of the computed WQ_v.
- The filter area is sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand should be used. The filter bed is typically designed to completely drain in 40 hours or less.
- The filter media should consist of a 12- to 18-inch layer of clean washed medium sand (meeting ASTM C-33 concrete sand or GADOT Fine Aggregate Size No. 10) on top of the underdrain system. Figure 3.2.4-4 illustrates a typical media cross section.
- The perimeter sand filter is equipped with a 4 inch perforated PVC pipe (AASHTO M 252) underdrain in a gravel layer. The underdrain must have a minimum grade of ⅛-inch per foot (1% slope). Holes should be ⅜-inch diameter and spaced approximately 6 inches on center. A permeable filter fabric should be placed between the gravel layer and the filter media. Gravel should be clean washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40% (GADOT No.3 Stone). Aggregate contaminated with soil shall not be used.

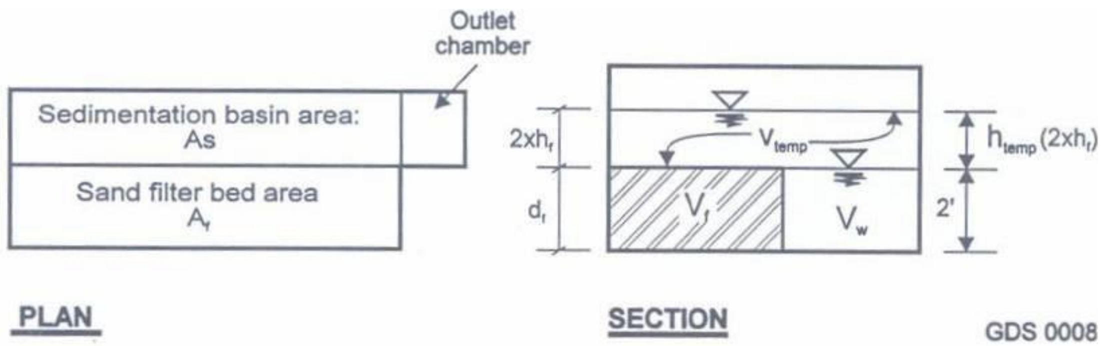


Figure 3.2.4-3 Perimeter Sand Filter Volumes
(Source: Claytor and Schueler, 1996)

D. PRETREATMENT / INLETS

- Pretreatment of runoff in a sand filter system is provided by the sedimentation chamber.
- Inlets to surface sand filters are to be provided with energy dissipators. Exit velocities from the sedimentation chamber must be nonerosive.
- Figure 3.2.4-5 shows a typical inlet pipe from the sedimentation basin to the filter media basin for the surface sand filter.

E. OUTLET STRUCTURES

- Outlet pipe is to be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways).

F. EMERGENCY SPILLWAY

- An emergency or bypass spillway must be included in the surface sand filter to safely pass flows that exceed the design storm flows. The spillway prevents filter water levels from overtopping the embankment and causing structural damage. The emergency spillway should be located so that downstream buildings and structures will not be impacted by spillway discharges.

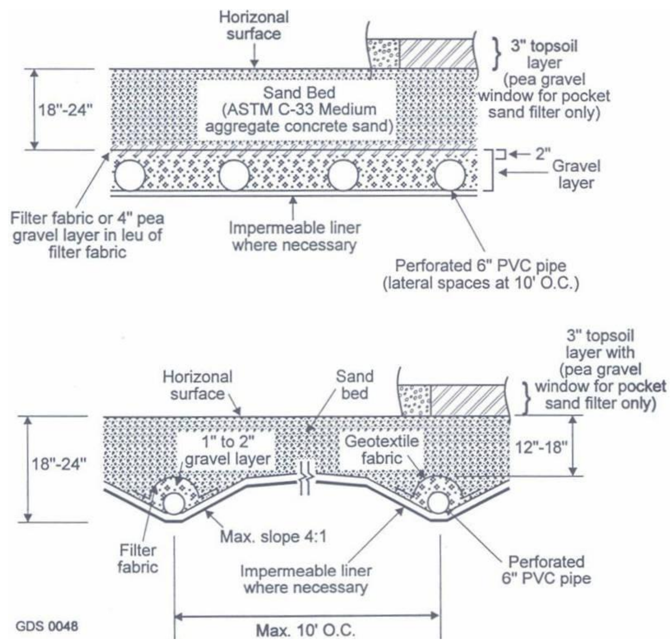


Figure 3.2.4-4 Typical Sand Filter Media Cross Sections
(Source: Claytor and Schueler, 1996)

G. MAINTENANCE ACCESS

- Adequate access must be provided for all sand filter systems for inspection and maintenance, including the appropriate equipment and vehicles. Access grates to the filter bed need to be included in a perimeter sand filter design. Facility designs must enable maintenance personnel to easily replace upper layers of the filter media.

H. SAFETY FEATURES

- Surface sand filter facilities can be fenced to prevent access. Inlet and access grates to perimeter sand filters may be locked.

I. LANDSCAPING

- Surface filters can be designed with a grass cover to aid in pollutant removal and prevent clogging. The grass should be capable of withstanding frequent periods of inundation and drought.

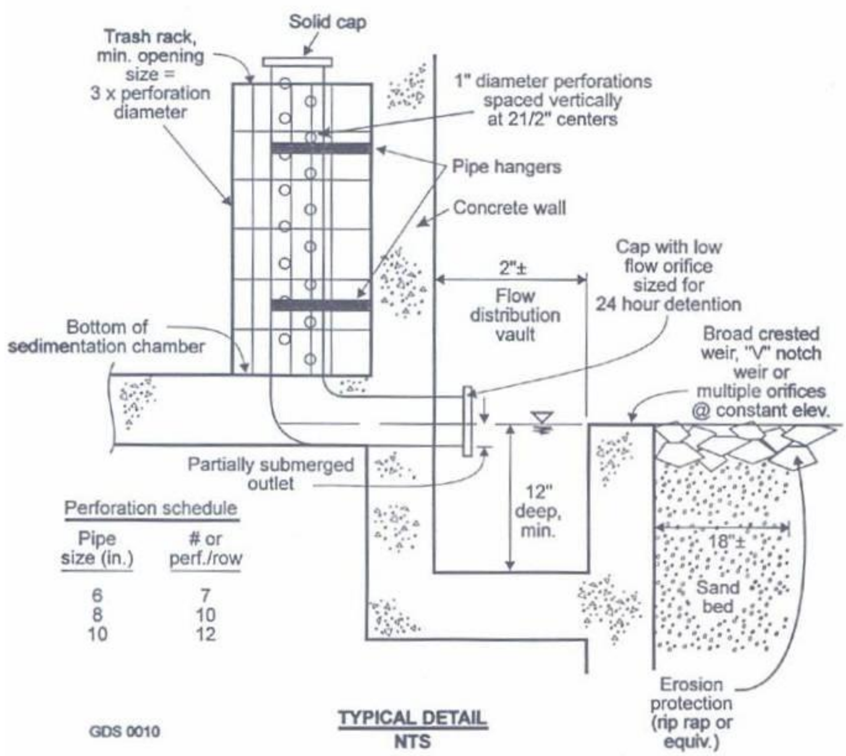


Figure 3.2.4-5 Surface Sand Filter Perforated Stand-Pipe
(Source: Claytor and Schueler, 1996)

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Use of surface sand filter may be limited by low head
- High Relief – Filter bed surface must be level
- Karst – Use poly-liner or impermeable membrane to seal bottom of earthen surface sand filter or use watertight structure

Soils

- No restrictions

Special Downstream Watershed Considerations

- Aquifer Protection – Use poly-liner or impermeable membrane to seal bottom of earthen surface sand filter or use watertight structure; no exfiltration of filter runoff into groundwater

3.2.4.6 Design Procedures

Step 1: Compute runoff control volumes from the Unified Stormwater Sizing Criteria.

A. Calculate the Water Quality Volume (WQ_v), Channel Protection Volume (Cp_v), Overbank Flood Protection Volume (Q_p), and the Extreme Flood Volume (Q_f).

B. Details on the Unified Stormwater Sizing Criteria are found in Section 1.3.

Step 2: Determine if the development site and conditions are appropriate for the use of a surface or perimeter sand filter.

A. Consider the Application and Site Feasibility Criteria in subsections 3.2.4.4 and 3.2.4.5-A (Location and Siting).

Step 3: Confirm Columbia County's design criteria and applicability.

A. Consider any special site-specific design conditions/criteria from subsection 3.2.4.5-J. (Additional Site-Specific Design Criteria and Issues).

B. Check with Columbia County officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4: Compute WQ_v peak discharge (Q_{wq}).

A. The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see subsection 2.1.7).

(a) Using WQ_v, compute CN

(b) Compute time of concentration using TR-55 method

(c) Determine appropriate unit peak discharge from time of concentration

(d) Compute Q_{wq} from unit peak discharge, drainage area, and WQ_v.

Step 5: Size flow diversion structure, if needed.

A. A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQ_v to the sand filter facility.

B. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 6: Size filtration basin chamber.

A. The filter area is sized using the following equation (based on Darcy's Law):

$$\mathbf{A_f = (WQ_v)(d_f)/[(k)(h_f + d_f)(t_f)]}$$

Where:

A_f = surface area of filter bed (ft^2)

d_f = filter bed depth
(typically 18 inches, no more than 24 inches)

k = coefficient of permeability of filter media (ft / day)
(use 3.5 ft / day for sand)

h_f = average height of water above filter bed (ft)
(½ h_{max}, which varies based on site but h_{max} is typically ≤ 6 feet)

t_f = design filter bed drain time (days)
(1.67 days or 40 hours is recommended maximum)

B. Set preliminary dimensions of filtration basin chamber.

C. See subsection 3.2.4.5-C (Physical Specifications / Geometry) for filter media specifications.

Step 7: Size sedimentation chamber.

A. ***Surface sand filter:*** The sedimentation chamber should be sized to at least 25% of the computed WQ_v and have a length-to-width ratio of 2:1. The Camp-Hazen equation is used to compute the required surface area:

$$\mathbf{A_s = -(Q_o / w) * Ln(1 - E)}$$

a. Where:

A_s = sedimentation basin surface area (ft^2)
Q_o = rate of outflow = the WQ_v over a 24-hour period
w = particle settling velocity (ft/sec)
E = trap efficiency

b. Assuming:

- 90% sediment trap efficiency (0.9)
- particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness < 75%
- particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness ≥ 75%
- average of 24 hour holding period

c. Then:

$$\mathbf{A_s = (0.066)(WQ_v)\ ft^2\ \text{for}\ I < 75\%}$$

$$\mathbf{A_s = (0.0081)(WQ_v)\ ft^2\ \text{for}\ I \geq 75\%}$$

d. Set preliminary dimensions of sedimentation chamber.

B. ***Perimeter sand filter:*** The sedimentation chamber should be sized to at least 50% of the computed WQ_v. Use same approach as for surface sand filter.

Step 8: Compute V_{min}.

A. $\mathbf{V_{min} = 0.75 * WQ_v}$

Step 9: Compute storage volumes within entire facility and sedimentation chamber orifice size.

A. ***Surface Sand Filter:***

$$\mathbf{V_{min} = 0.75\ WQ_v = V_s + V_f + V_{f-temp}}$$

(1) Compute V_f = water volume within filter bed / gravel / pipe = $\mathbf{A_f * d_f * n}$

Where: n = porosity = 0.4 for most applications

(2) Compute $V_{f\text{-}temp}$ = temporary storage volume above the filter bed = $\mathbf{2 * h_f * A_f}$

(3) Compute V_s = volume within sediment chamber = $\mathbf{V_{min} - V_f + V_{f-temp}}$

(4) Compute h_s = height in sedimentation chamber = $\mathbf{V_s / A_s}$

(5) Ensure h_s and h_f fit available head and other dimensions still fit – change as necessary in design iterations until all site dimensions fit.

(6) Size orifice from sediment chamber to filter chamber to release V_s within 24-hours at average release rate with 0.5 h_s as average head.

(7) Design outlet structure with perforations allowing for a safety factor of 10 (see example).

(8) Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

B. ***Perimeter Sand Filter:***

(1) Compute V_f = water volume within filter bed / gravel / pipe = $\mathbf{A_f * d_f * n}$

Where: n = porosity = 0.4 for most applications

(2) Compute V_w = wet pool storage volume $\mathbf{A_s * 2}$ feet minimum

(3) Compute V_{temp} = temporary storage volume = $\mathbf{V_{min} - (V_f + V_w)}$

(4) Compute h_{temp} = temporary storage height = $\mathbf{V_{temp} - (A_f + A_s)}$

(5) Ensure $\mathbf{h_{temp} \geq 2 * h_f}$; otherwise decrease h_f and re-compute. Ensure dimensions fit available head and area – change as necessary in design iterations until all site dimensions fit.

(6) Size distribution slots from sediment chamber to filter chamber.

Step 10: Design inlets, pretreatment facilities, underdrain system, and outlet structures.

A. See subsection 3.2.4.5-D through H for more details.

Step 11: Compute overflow weir sizes.

A. ***Surface sand filter:***

(1) Size overflow weir at elevation h_s in sedimentation chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 50-year storm (see example).

(2) Plan inlet protection for overflow from sedimentation chamber and size overflow weir at elevation h_f in filtration chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 50-year storm (see example).

B. ***Perimeter sand filter:*** Size overflow weir at end of sedimentation chamber to handle excess inflow, set at WQ_v elevation.

See Appendix D-3 for a Sand Filter Design Example

3.2.4.7 Inspection and Maintenance Requirements

Activity	Schedule
• Ensure that contributing area, facility, inlets and outlets are clear of debris. • Ensure that the contributing area is stabilized and mowed, with clippings removed. • Remove trash and debris. • Check to ensure that the filter surface is not clogging (also check after moderate and major storms). • Ensure that activities in the drainage area minimize oil / grease and sediment entry to the system. • If permanent water level is present (perimeter sand filter), ensure that the chamber does not leak, and normal pool level is retained.	Monthly
• Check to see that the filter bed is clean of sediment, and the sediment chamber is not more than 50% full or 6 inches, whichever is less, of sediment. Remove sediment as necessary. • Make sure that there is no evidence of deterioration, spalling or cracking of concrete. • Inspect grates (perimeter sand filter). • Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. • Repair or replace any damaged structural parts. • Stabilize any eroded areas. • Ensure that flow is not bypassing the facility. • Ensure that no noticeable odors are detected outside the facility.	Annually
• If filter bed is clogged or partially clogged, manual manipulation of the surface layer of sand may be required. Remove the top few inches of sand, roto-till or otherwise cultivate the surface, and replace media with sand meeting the design specifications. • Replace any filter fabric that has become clogged.	As Needed

Table 3.2.4-1 Typical Maintenance Activities for Sand Filters
(Source: WMI, 1997; Pitt, 1997)

Additional Maintenance Considerations and Requirements

- A record should be kept of the dewatering time for a sand filter to determine if maintenance is necessary.
- When the filtering capacity of the sand filter facility diminishes substantially (i.e., when water ponds on the surface of the filter bed for more than 48 hours), then the top layers of the filter media (topsoil and 2 to 3 inches of sand) will need to be removed and replaced. This will typically need to be done every 3 to 5 years for low sediment applications, more often for areas of high sediment yield or high oil and grease.
- Removed sediment and media may usually be disposed of in a landfill.

Regular inspection and maintenance is critical to the effective operation of sand filters facilities as designed. Maintenance responsibility for this BMP should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval. **Columbia County will not accept ownership of or maintain this type of BMP.**

3.2.4.8 Example Schematics

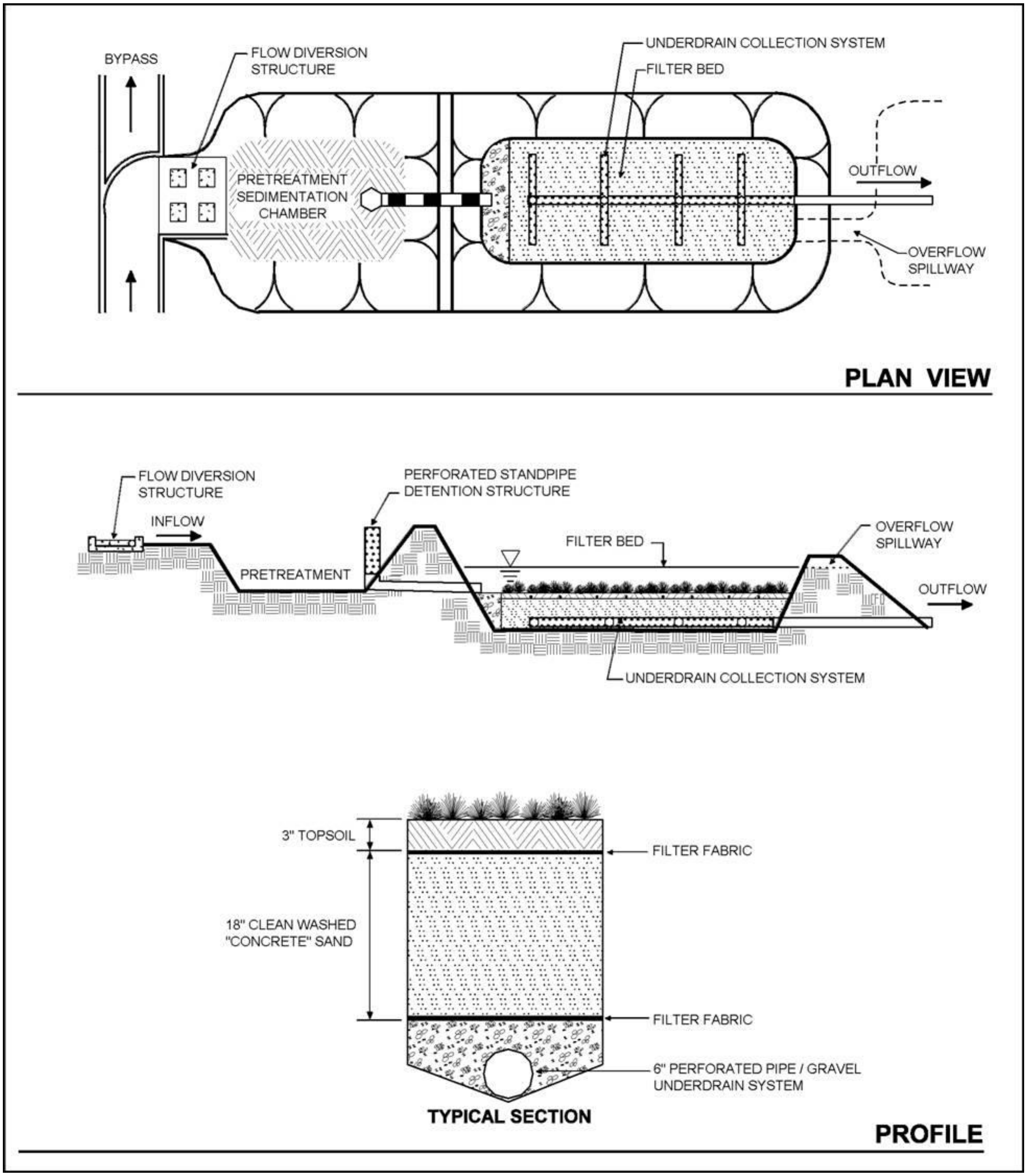


Figure 3.2.4-6 Schematic of Surface Sand Filter

(Source: Center for Watershed Protection)

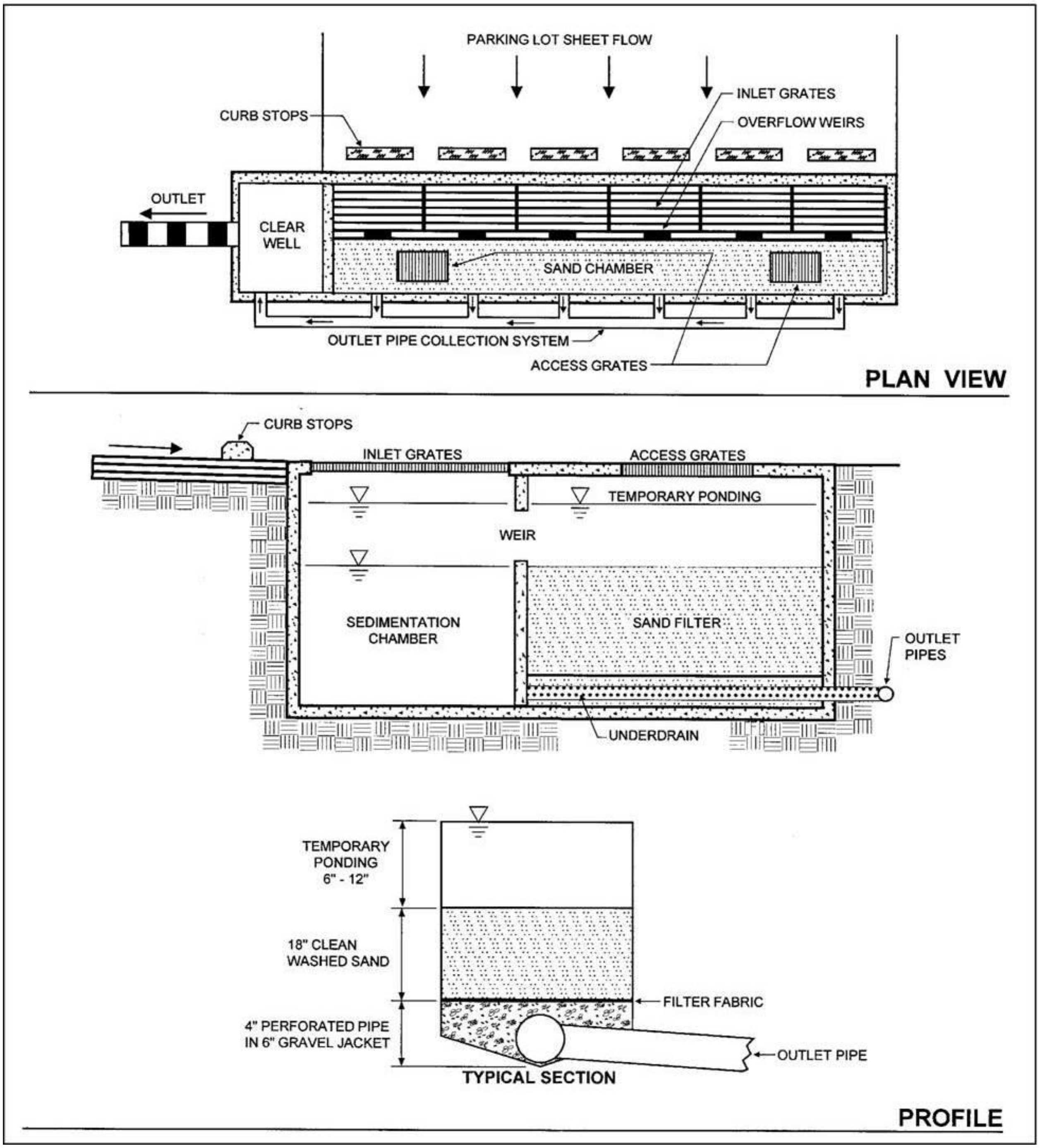


Figure 3.2.4-7 Schematic of Perimeter Sand Filter

(Source: Center for Watershed Protection)

3.2.4.9 Design Forms

Design Procedure Form: Sand Filters

PRELIMINARY HYDROLOGIC CALCULATIONS		
1a) Compute WQ_v volume requirements		
Compute Runoff Coefficient, R_v	R_v = ________	
Compute WQ_v	WQ_v = ________	acre - ft
1b) Compute Cp_v	Cp_v = ________	acre - ft
Compute average release rate	release rate = ________	cfs
Compute Q_{p50}	Q_{p50} = ________	acre - ft
Compute (as necessary) Q_f	Q_f = ________	acre - ft
SAND FILTER DESIGN		
2) Is the use of a sand filter appropriate?	Low Point in development area = ________	
	Low Point at stream invert = ________	
	Total available head = ________	
	Average depth, h_f = ________	
	See subsections 3.2.4.4 and 3.2.4.5-A	
3) Confirm local design criteria and applicability	**See subsection 3.2.4.5-J**	
4) Compute WQ_v peak discharge (Q_{wq})		
Compute Curve Number	CN = ________	
Compute Time of Concentration	t_c = ________	hour
Compute Q_{wq}	Q_{wq} = ________	cfs
5) Size flow diversion structure	A = ________	ft^2
Low flow orifice - Orifice equation	diameter = ________	inch
Overflow weir - Weir equation	Length = ________	ft
6) Size filtration bed chamber	A_f = ________	ft^2
Compute area from Darcy's Law	L = ________	ft
Using length to width (2:1) ratio	W = ________	ft
7) Size sedimentation chamber		
Compute area from Camp-Hazen equation	A_s = ________	ft^2
Given W from step 5, compute Length	L = ________	ft
8) Compute V_{min}	V_{min} = ________	ft^3
9) Compute volume within practice		
Surface Sand Filter	V_f = ________	ft^3
Volume within filter bed	$V_{f\text{-}temp}$ = ________	ft^3
Temporary storage above filter bed	V_s = ________	ft^3
Sedimentation chamber (remaining volume	H_s = ________	ft
Height in sedimentation chamber	A = ________	ft^2
Perforated stand pipe - Orifice equation	diameter = ________	inch
Perimeter Sand Filter	V_f = ________	ft^3
Compute volume in filter bed	V_w = ________	ft^3
Compute wet pool storage	V_{temp} = ________	ft^3
Compute temporary storage	h_{temp} = ________	ft
10) Compute overflow weir sizes		
Compute overflow - Orifice equation	Q = ________	cfs
Weir from sedimentation chamber - Weir equation	Length = ________	ft
Weir from filtration chamber - Weir equation	Length = ________	ft

Notes: ____

3.2.5 Infiltration Trench

General Application
Structural Stormwater Control

Description: Excavated trench filled with stone aggregate used to capture and allow infiltration of stormwater runoff into the surrounding soils from the bottom and sides of the trench.

KEY CONSIDERATIONS

DESIGN CRITERIA:

- Soil infiltration rate of 0.5in/hr or greater required
- Excavated trench (3 to 8 foot depth) filled with stone media (1.5- to 2.5-inch diameter); pea gravel and sand filter layers
- A sediment forebay and grass channel or equivalent upstream pretreatment, must be provided
- Observation well to monitor percolation

ADVANTAGES / BENEFITS:

- Provides for groundwater recharge
- Good for small sites with porous soils

DISADVANTAGES / LIMITATIONS:

- Potential for groundwater contamination
- High clogging potential; should not be used on sites with fine-particled soils (clays or silts) in drainage area
- Significant setback requirements
- Restrictions in karst areas
- Geotechnical testing required, two borings per facility

MAINTENANCE REQUIREMENTS:

- Inspect for clogging
- Remove sediment from forebay
- Replace pea gravel layer as needed

POLLUTANT REMOVAL

80%	**Total Suspended Solids**
60 / 60%	**Nutrients –** Total Phosphorus / Total Nitrogen removal
90%	**Metals** – Cadmium, Copper, Lead, and Zinc removal
90%	**Pathogens** – Coliform, Streptococci, E.Coli removal

STORMWATER MANAGEMENT SUITABILITY

☑ **Water Quality**

✪ **Channel Protection**

☐ **Overbank Flood Protection**

☐ **Extreme Flood Protection**

Accepts Hotspot Runoff: *No*

✪ in certain situations

IMPLEMENTATION CONSIDERATIONS

M	**Land Requirement**
H	**Capital Cost**
H	**Maintenance Burden**

Residential Subdivision Use: *Yes*

High Density / Ultra – Urban: *Yes*

Drainage Area: *5 acres* max.

Soils: *Pervious soils required (0.5 in / hr or greater)*

Other Considerations:

- *Must not be placed under pavement or concrete*

L=Low **M**=Moderate **H**=High

3.2.5.1 General Description

Infiltration trenches are excavations typically filled with stone to create an underground reservoir for stormwater runoff (see Figure 3.2.5-1). This runoff volume gradually exfiltrates through the bottom and sides of the trench into the subsoil over a 2-day period and eventually reaches the water table. By diverting runoff into the soil, an infiltration trench not only treats the water quality volume, but also helps to preserve the natural water balance on a site and can recharge groundwater and preserve baseflow. Due to this fact, infiltration systems are limited to areas with highly porous soils where the water table and/or bedrock are located well below the bottom of the trench. In addition, infiltration trenches must be carefully sited to avoid the potential of groundwater contamination.

Infiltration trenches are not intended to trap sediment and must always be designed with a sediment forebay and grass channel or filter strip, or other appropriate pretreatment measures to prevent clogging and failure. Due to their high potential for failure, these facilities must only be considered for sites where upstream sediment control can be ensured.

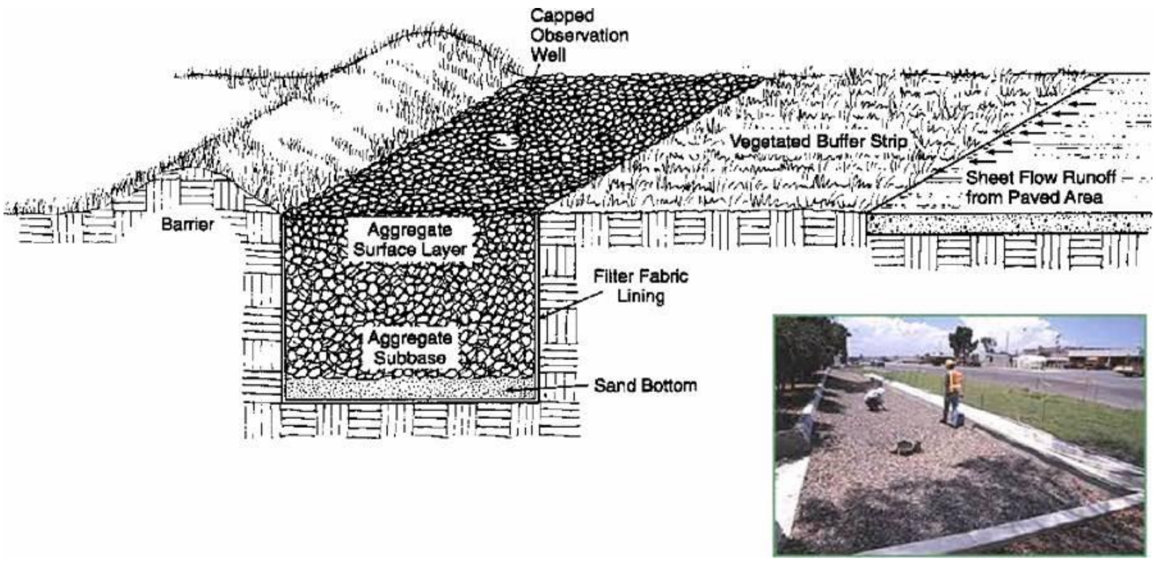


Figure 3.2.5-1 Infiltration Trench Example

3.2.5.2 Stormwater Management Suitability

Infiltration trenches are designed primarily for stormwater quality, i.e. the removal of stormwater pollutants. However, they can provide limited runoff quantity control, particularly for smaller storm events. For some smaller sites, trenches can be designed to capture and infiltrate the channel protection volume (Cp_v) in addition to WQ_v. An infiltration trench will need to be used in conjunction with another structural control to provide overbank and extreme flood protection, if required.

Water Quality

Using the natural filtering properties of soil, infiltration trenches can remove a wide variety of pollutants from stormwater through sorption, precipitation, filtering, and bacterial and chemical degradation. Sediment load and other suspended solids are removed from runoff by pretreatment measures in the facility that treats flows before they reach the trench surface.

Section 3.2.5.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

Channel Protection

For smaller sites, an infiltration trench may be designed to capture and infiltrate the entire channel protection volume Cp_v in either an off- or on-line configuration. For larger sites, or where only the WQ_v is diverted to the trench, another structural control must be used to provide Cp_v extended detention.

Overbank Flood Protection

Another structural control must be used in conjunction with an infiltration trench system to reduce the post-development peak flow of the 50-year storm (Q_p) to pre-development levels (detention).

Extreme Flood Protection

Infiltration trench facilities must provide flow diversion and/or be designed to safely pass extreme storm flows and protect the filter bed and facility.

Credit for the volume of runoff removed and treated by the infiltration trench may be taken in the overbank flood protection and extreme flood protection calculations (see Section 3.1).

3.2.5.3 Pollutant Removal Capabilities

An infiltration trench is presumed to be able to remove up to 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed infiltration trenches can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or "treatment train" approach.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – 60%**
- **Total Nitrogen – 60%**
- **Fecal Coliform – 90%**
- **Heavy Metals – 90%**

3.2.5.4 Application and Site Feasibility Criteria

Infiltration trenches are generally suited for medium-to-high density residential, commercial and institutional developments where the subsoil is sufficiently permeable to provide a reasonable infiltration rate and the water table is low enough to prevent groundwater contamination. They are applicable primarily for impervious areas where there are not high levels of fine particulates (clay/silt soils) in the runoff and should only be considered for sites where the sediment load is relatively low.

Infiltration trenches can either be used to capture sheet flow from a drainage area or function as an off-line device. Due to the relatively narrow shape, infiltration trenches can be adapted to many different types of sites and can be utilized in retrofit situations. Unlike some other structural stormwater controls, they can easily fit into the margin, perimeter, or other unused areas of developed sites.

To protect groundwater from potential contamination, runoff from designated hotspot land uses or activities must not be infiltrated. Infiltration trenches should not be used for manufacturing and industrial sites, where there is a potential for high concentrations of soluble pollutants and heavy metals. In addition, infiltration should not be considered for areas with a high pesticide concentration. Infiltration trenches are also not suitable in areas with karst geology without adequate geotechnical testing by qualified individuals and in accordance with Columbia County requirements.

The following criteria should be evaluated to ensure the suitability of an infiltration trench for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage – YES
- Suitable for High Density/Ultra Urban Areas – YES
- Regional Stormwater Control – NO

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 5 acres maximum
- Space Required – Will vary depending on the depth of the facility
- Site Slope – No more than 6% slope (for pre-construction facility footprint)
- Minimum Head – Elevation difference needed at a site from the inflow to the outflow: 1 foot
- Minimum Depth to Water Table – 4 feet recommended between the bottom of the infiltration trench and the elevation of the seasonally high water table, may be reduced to 2 feet in coastal areas
- Soils – Infiltration rate greater than 0.5 inches per hour required (typically hydrologic group "A", some group "B" soils)

Other Constraints / Considerations

- Aquifer Protection – No hotspot runoff allowed; Meet setback requirements in design criteria

3.2.5.5 Planning and Design Criteria

The following criteria are to be considered ***minimum*** *standards for the design of an infiltration trench facility. Consult with Columbia County to determine if there are any variations to these criteria or additional standards that must be followed.*

A. LOCATION AND SITING

- To be suitable for infiltration, underlying soils should have an infiltration rate (f_c) of 0.5 inches per hour or greater, as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5,000 square feet, with a minimum of two borings per facility (taken within the proposed limits of the facility). Infiltration trenches cannot be used in fill soils.
- Infiltration trenches should have a contributing drainage area of 5 acres or less.
- Soils on the drainage area tributary to an infiltration trench should have a clay content of less than 20% and a silt/clay content of less than 40% to prevent clogging and failure.
- There should be at least 4 feet between the bottom of the infiltration trench and the elevation of the seasonally high water table.
- Clay lenses, bedrock or other restrictive layers below the bottom of the trench will reduce infiltration rates unless excavated.
- Minimum setback requirements for infiltration trench facilities:
  - From a property line – 10 feet
  - From a building foundation – 25 feet
  - From a private well – 100 feet
  - From a public water supply well – 1,200 feet
  - From a septic system tank/leach field – 100 feet
  - From surface waters – 100 feet
  - From surface drinking water sources – 400 feet (100 feet for a tributary)
- When used in an off-line configuration, the water quality volume (WQ_v) is diverted to the infiltration trench through the use of a flow splitter. Stormwater flows greater than the WQ_v are diverted to other controls or downstream using a diversion structure or flow splitter.
- To reduce the potential for costly maintenance and/or system reconstruction, it is strongly recommended that the trench be located in an open or lawn area, with the top of the structure as close to the ground surface as possible. Infiltration trenches shall not be located beneath paved surfaces, such as parking lots.

- Infiltration trenches are designed for intermittent flow and must be allowed to drain and allow reaeration of the surrounding soil between rainfall events. They must not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

B. GENERAL DESIGN

- A well-designed infiltration trench consists of:
  - **(1)** Excavated shallow trench backfilled with sand, coarse stone, and pea gravel, and lined with a filter fabric;
  - **(2)** Appropriate pretreatment measures; and
  - **(3)** One or more observation wells to show how quickly the trench dewaters or to determine if the device is clogged.

Figure 3.2.5-2 provides a plan view and profile schematic for the design of an off-line infiltration trench facility. An example of an on-line infiltration trench is shown in Figure 3.2.5-1.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- The required trench storage volume is equal to the water quality volume (WQ_v). For smaller sites, an infiltration trench can be designed with a larger storage volume to include the channel protection volume (Cp_v).
- A trench must be designed to fully dewater the entire WQ_v within 24 to 48 hours after a rainfall event. The slowest infiltration rate obtained from tests performed at the site should be used in the design calculations.
- Trench depths should be between 3 and 8 feet, to provide for easier maintenance. The width of a trench must be less than 25 feet.
- Broader, shallow trenches reduce the risk of clogging by spreading the flow over a larger area for infiltration.
- The surface area required is calculated based on the trench depth, soil infiltration rate, aggregate void space, and fill time (assume a fill time of 2 hours for most designs).
- The bottom slope of a trench should be flat across its length and width to evenly distribute flows, encourage uniform infiltration through the bottom, and reduce the risk of clogging.
- The stone aggregate used in the trench should be washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40% (GADOT No.3 Stone). Aggregate contaminated with soil shall not be used. A porosity value (void space/total volume) of 0.32 should be used in calculations, unless aggregate specific data exist.
- A 6-inch layer of clean, washed sand is placed on the bottom of the trench to encourage drainage and prevent compaction of the native soil while the stone aggregate is added.
- The infiltration trench is lined on the sides and top by an appropriate geotextile filter fabric that prevents soil piping but has greater permeability than the parent soil. The top layer of filter fabric is located 2 to 6 inches from the top of the trench and serves to prevent sediment from passing into the stone aggregate. Since this top layer serves as a sediment barrier, it will need to be replaced more frequently and must be readily separated from the side sections.
- The top surface of the infiltration trench above the filter fabric is typically covered with pea gravel. The pea gravel layer improves sediment filtering and maximizes the pollutant removal in the top of the trench. In addition, it can easily be removed and replaced should the device begin to clog. Alternatively, the trench can be covered with permeable topsoil and planted with grass in a landscaped area.
- An observation well must be installed in every infiltration trench and should consist of a perforated PVC pipe, 4 to 6 inches in diameter, extending to the bottom of the trench (see Appendix B for a schematic of an observation well). The observation well will show the rate of dewatering after a storm, as well as provide a means of determining sediment levels at the bottom and when the filter fabric at the top is clogged and maintenance is needed. It should be installed along the centerline of the structure, flush with the ground elevation of the trench.

A visible floating marker should be provided to indicate the water level. The top of the well should be capped and locked to discourage vandalism and tampering.

- The trench excavation should be limited to the width and depth specified in the design. Excavated material should be placed away from the open trench so as not to jeopardize the stability of the trench sidewalls. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction, and should be scarified prior to placement of sand. The sides of the trench shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling. All infiltration trench facilities should be protected during site construction and should be constructed after upstream areas have been stabilized.

D. PRETREATMENT / INLETS

- Pretreatment facilities must always be used in conjunction with an infiltration trench to prevent clogging and failure.
- For a trench receiving sheet flow from an adjacent drainage area, the pretreatment system should consist of a vegetated filter strip with a minimum 25-foot length. A vegetated buffer strip around the entire trench is required if the facility is receiving runoff from both directions. If the infiltration rate for the underlying soils is greater than 2 inches per hour, 50% of the WQ_v should be pretreated by another method prior to reaching the infiltration trench.
- For an off-line configuration, pretreatment should consist of a sediment forebay, vault, plunge pool, or similar sedimentation chamber (with energy dissipators) sized to 25% of the water quality volume (WQ_v). Exit velocities from the pretreatment chamber must be nonerosive for the 2-year design storm.

E. OUTLET STRUCTURES

- Outlet structures are not required for infiltration trenches.

F. EMERGENCY SPILLWAY

- Typically for off-line designs, there is no need for an emergency spillway. However, a nonerosive overflow channel should be provided to safely pass flows that exceed the storage capacity of the trench to a stabilized downstream area or watercourse.

G. MAINTENANCE ACCESS

- Adequate access should be provided to an infiltration trench facility for inspection and maintenance.

H. SAFETY FEATURES

- In general, infiltration trenches are not likely to pose a physical threat to the public and do not need to be fenced.

I. LANDSCAPING

- Vegetated filter strips and buffers should fit into and blend with surrounding area. Native grasses are preferable, if compatible. The trench may be covered with permeable topsoil and planted with grass in a landscaped area

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – No additional criteria
- High Relief – Maximum site slope of 6%

Special Downstream Watershed Considerations

- No additional criteria

3.2.5.6 Design Procedures

Step 1: Compute runoff control volumes from the Unified Stormwater Sizing Criteria.

A. Calculate the Water Quality Volume (WQ_v), Channel Protection Volume (Cp_v), Overbank Flood Protection Volume (Q_p), and the Extreme Flood Volume (Q_f).

B. Details on the Unified Stormwater Sizing Criteria are found in Section 1.3.

Step 2: Determine if the development site and conditions are appropriate for the use of a stormwater pond.

A. Consider the Application and Site Feasibility Criteria in subsections 3.2.5.4 and 3.2.5.5-A (Location and Siting).

Step 3: Confirm Columbia County's design criteria and applicability.

A. Consider any special site-specific design conditions/criteria from subsection 3.2.5.5-J. (Additional Site-Specific Design Criteria and Issues).

B. Check with Columbia County officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4: Compute WQ_v peak discharge (Q_{wq}).

A. The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see subsection 2.1.7).

(a) Using WQ_v (or total volume to be captured), compute CN

(b) Compute time of concentration using TR-55 method

(c) Determine appropriate unit peak discharge from time of concentration

(d) Compute Q_{wq} from unit peak discharge, drainage area, and WQ_v.

Step 5: Size flow diversion structure, if needed.

A. A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQ_v to the infiltration trench.

B. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 6: Size infiltration trench.

A. The area of the trench can be determined from the following equation:

$$\mathbf{A = \frac{WQ_v}{(nd + kT/12)}}$$

Where:

A = surface area

WQ_v = water quality volume (or total volume to be infiltrated)

n = porosity (feet)

d = trench depth (feet)

k = percolation (inches / hour)

T = Fill Time (time for the practice to fill with water), in hours

B. A porosity value $n = 0.32$ should be used.

C. All infiltration systems should be designed to fully dewater the entire WQ_v within 24 to 48 hours after the rainfall event.

D. A fill time *T=2 hours* can be used for most designs

E. See subsection 3.2.5.5-C (Physical Specifications / Geometry) for more specifications.

Step 7: Determine pretreatment volume and design pretreatment measures.

A. Size pretreatment facility to treat 25% of the water quality volume (WQ_v) for off-line configurations.

B. See subsection 3.2.5.5-D (Pretreatment / Inlets) for more details.

Step 8: Design spillway(s).

A. Adequate stormwater outfalls should be provided for the overflow exceeding the capacity of the trench, ensuring nonerosive velocities on down-slope.

<u>See Appendix D-4 for an Infiltration Trench Design Example</u>

3.2.5.7 Inspection and Maintenance Requirements

Activity	Schedule
• Ensure that contributing area, facility, inlets and outlets are clear of debris. • Ensure that the contributing area is stabilized. • Remove sediment and oil / grease from pretreatment devices, as well as overflow structures. • Mow grass filter strips should be mowed as necessary. Remove grass clippings.	Monthly
• Check observation wells following 3 days of dry weather. Failure to percolate within this time period indicates clogging. • Inspect pretreatment devices and diversion structures for sediment build-up and structural damage. • Remove trees that start to grow in the vicinity of the trench.	Annually
• Replace pea gravel / topsoil and top surface filter fabric (when clogged).	As Needed
• Perform total rehabilitation of the trench to maintain design storage capacity. • Excavate trench walls to expose clean soil.	Upon Failure

Table 3.2.5-1 Typical Maintenance Activities for Infiltration Trenches
(Source: EPA, 1999)

Additional Maintenance Considerations and Requirements

- A record should be kept of the dewatering time of an infiltration trench to determine if maintenance is necessary.
- Removed sediment and media may usually be disposed of in a landfill.

Regular inspection and maintenance is critical to the effective operation of enhanced swales as designed. Maintenance responsibility for this BMP should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval. **Columbia County will not accept ownership of or maintain this type of BMP.**

3.2.5.8 Example Schematics

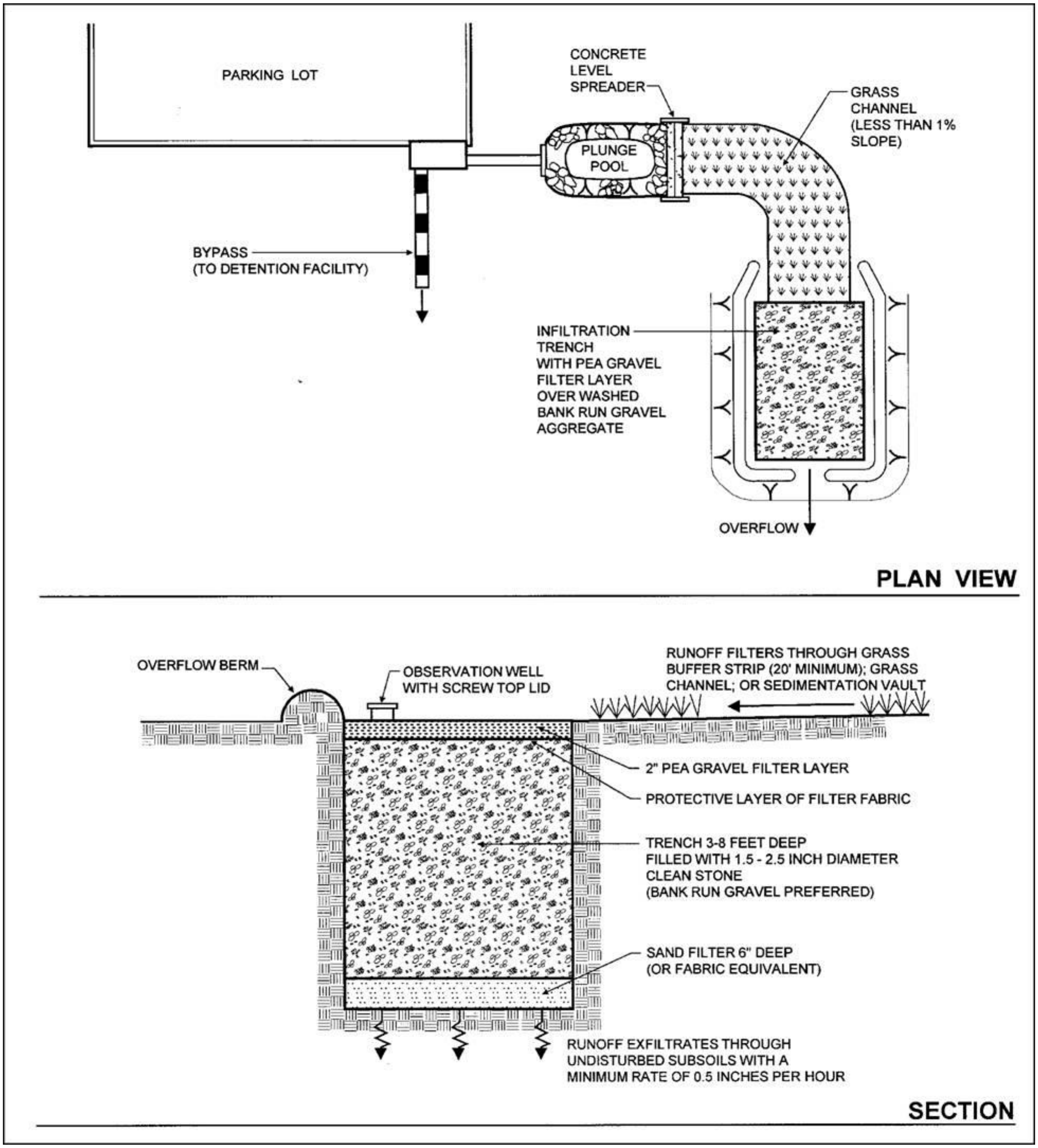
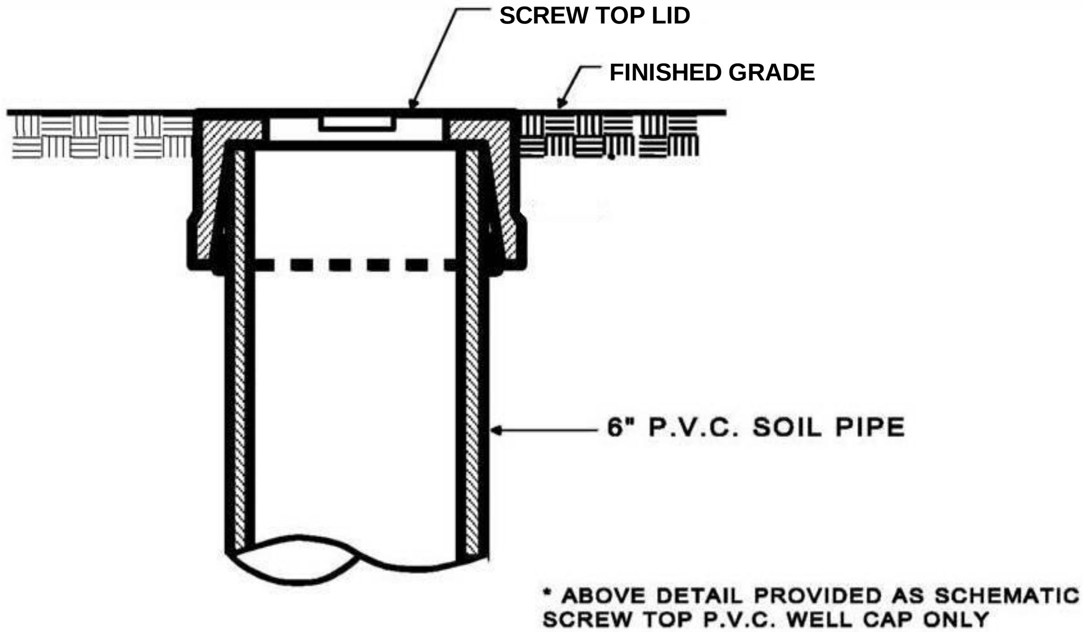


Figure 3.2.5-2 Schematic of Infiltration Trench

(Source: Center for Watershed Protection)



Each Observation Well / Cleanout shall include the following:

1. **For an underground flush mounted observation well / cleanout, provide a tube made of non-corrosive material, schedule 40 or equal, at least three feet long with an inside diameter of at least 6 inches.**

2. **The tube shall have a factory attached cast iron or high impact plastic collar with ribs to prevent rotation when removing screw top lid. The screw top lid shall be cast iron or high impact plastic that will withstand ultra-violet rays.**

OBSERVATION WELL DETAIL

Figure 3.2.5-3 Observation Well Detail

3.2.5.9 Design Forms

Design Procedure Form: Infiltration Trench

PRELIMINARY HYDROLOGIC CALCULATIONS		
1a) Compute WQ_v volume requirements		
Compute Runoff Coefficient, R_v	R_v = ______	
Compute WQ_v	WQ_v = ______	acre - ft
1b) Compute Cp_v	Cp_v = ______	acre - ft
Compute average release rate	release rate = ______	cfs
Compute Q_{p50}	Q_{p50} = ______	acre - ft
Compute (as necessary) Q_f	Q_f = ______	acre - ft
INFILTRATION TRENCH DESIGN		
2) Is the use of a infiltration trench appropriate?	**See subsections 3.2.5.4 and 3.2.5.5-A**	
3) Confirm local design criteria and applicability	**See subsection 3.2.5.5-J**	
4) Compute WQ_v peak discharge (Q_{wq})		
Compute Curve Number	CN = ______	
Compute Time of Concentration (t_c)	t_c = ______	hour
Compute Q_{wq}	Q_{wq} = ______	cfs
5) Size infiltration trench		
Width must be less than 25 ft	Area= ______	ft^2
	Width = ______	ft
	Length = ______	ft
6) Size the flow diversion structures		
Low flow orifice from orifice equation	A = ______	ft^2
$Q = CA\,(2gh)^{0.5}$	diameter = ______	inch
Overflow weir from weir equation		
$Q = CLH^{3/2}$	Length = ______	ft
7) Pretreatment volume (for offline designs)		
$Vol_{pre} = 0.25\,(WQ_v)$	Vol_{pre} = ______	ft^3
8) Design spillway(s)		

Notes: ____

____

____

____

3.2.6 Enhanced Swales

Description: Vegetated open channels that are explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other means.

KEY CONSIDERATIONS

DESIGN CRITERIA:

- Longitudinal slopes must be less than 4%
- Bottom width of 2 to 8 feet
- Side slopes 2:1 or flatter; 4:1 recommended
- Convey the 25-year storm event with a minimum of 6 inches of freeboard

ADVANTAGES / BENEFITS:

- Combines stormwater treatment with runoff conveyance system
- Less expensive than curb and gutter
- Reduces runoff velocity

DISADVANTAGES / LIMITATIONS:

- Higher maintenance than curb and gutter systems
- Cannot be used on steep slopes
- Possible resuspension of sediment
- Potential for odor / mosquitoes (wet swale)

MAINTENANCE REQUIREMENTS:

- Maintain grass heights of approximately 4 to 6 inches (dry swale)
- Remove sediment from forebay and channel

POLLUTANT REMOVAL

80%	**Total Suspended Solids**
50 / 50%	**Nutrients –** Total Phosphorus / Total Nitrogen removal
40%	**Metals** – Cadmium, Copper, Lead, and Zinc removal
No data	**Pathogens** – Coliform, Streptococci, E.Coli removal

STORMWATER MANAGEMENT SUITABILITY

- ☑ **Water Quality**
- ✪ **Channel Protection**
- ☐ **Overbank Flood Protection**
- ☐ **Extreme Flood Protection**

Accepts Hotspot Runoff: *Yes (requires impermeable liner)*

✪ in certain situations

IMPLEMENTATION CONSIDERATIONS

H	**Land Requirement**
M	**Capital Cost**
L	**Maintenance Burden**

Residential Subdivision Use: *Yes*

High Density / Ultra – Urban: *No*

Drainage Area: *5 acres* max.

Soils: *No restrictions*

Other Considerations:

- *Permeable soil layer (dry swale)*
- *Wetland plants (wet swale)*

L=Low **M**=Moderate **H**=High

3.2.6.1 General Description

Enhanced swales (also referred to as *vegetated open channels* or *water quality swales*) are conveyance channels engineered to capture and treat the water quality volume (WQ_v) for a drainage area. They differ from a normal drainage channel or swale through the incorporation of specific features that enhance stormwater pollutant removal effectiveness.

Enhanced swales are designed with limited longitudinal slopes to force the flow to be slow and shallow, thus allowing for particulates to settle and limiting the effects of erosion. Berms and/or check dams installed perpendicular to the flow path promote settling and infiltration.

There are two primary enhanced swale designs, the *dry swale* and the *wet swale* (or *wetland channel*). Below are descriptions of these two designs:

- **Dry Swale** – The dry swale is a vegetated conveyance channel designed to include a filter bed of prepared soil that overlays an underdrain system. Dry swales are sized to allow the entire WQ_v to be filtered or infiltrated through the bottom of the swale. Because they are dry most of the time, they are often the preferred option in residential settings.
- **Wet Swale (Wetland Channel)** – The wet swale is a vegetated channel designed to retain water or marshy conditions that support wetland vegetation. A high water table or poorly drained soils are necessary to retain water. The wet swale essentially acts as a linear shallow wetland treatment system, where the WQ_v is retained.

Enhanced Dry Swale | **Enhanced Wet Swale**

Figure 3.2.6-1 Enhanced Swale Examples

Dry and wet swales are not to be confused with a *filter strip* or *grass channel*, which are Limited Application structural controls and not considered acceptable for meeting the TSS removal performance goal by them. Ordinary *grass channels* are not engineered to provide the same treatment capability as a well-designed dry swale with filter media. *Filter strips* are not designed to accommodate overland flow rather than channelized flow and can be used as stormwater credits to help reduce the total water quality treatment volume for a site. Both of these practices may be used for pretreatment or included in a “treatment train” approach where redundant treatment is provided. Please see a further discussion of these limited application structural controls in subsections 3.3.1 and 3.3.2, respectively.

3.2.6.2 Stormwater Management Suitability

Enhanced swale systems are designed primarily for stormwater quality and have only a limited ability to provide channel protection or to convey higher flows to other controls.

Water Quality

Dry swale systems rely primarily on filtration through an engineered media to provide removal of stormwater contaminants. Wet swales achieve pollutant removal both from sediment accumulation and biological removal.

Section 3.2.6.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

Channel Protection

Generally only the WQ_v is treated by a dry or wet swale, and another structural control must be used to provide Cp_v extended detention. However, for some smaller sites, a swale may be designed to capture and detain the full Cp_v.

Overbank Flood Protection

Enhanced swales must provide flow diversion and/or be designed to safely pass overbank flood flows. Another structural control must be used in conjunction with an enhanced swale system to reduce the post-development peak flow of the 50-year storm (Q_{p50}) to pre-development levels (detention).

Extreme Flood Protection

Enhanced swales must provide flow diversion and/or be designed to safely pass extreme storm flows. Another structural control must be used in conjunction with an enhanced swale system to reduce the post-development peak flow of the 100-year storm (Q_f) if necessary.

3.2.6.3 Pollutant Removal Capabilities

Both the dry and wet enhanced swale are presumed to be able to remove up to 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed swales can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or “treatment train” approach.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – Dry Swale 50% / Wet Swale 25%**
- **Total Nitrogen – Dry Swale 50% / Wet Swale 40%**
- **Fecal Coliform – insufficient data**
- **Heavy Metals – Dry Swale 40% / Wet Swale 20%**

3.2.6.4 Application and Feasibility Criteria

Enhanced swales can be used in a variety of development types; however, they are primarily applicable to residential and institutional areas of low to moderate density where the impervious cover in the contributing drainage area is relatively small, and along roads and highways. Dry swales are mainly used in moderate to large lot residential developments, small impervious areas (parking lots and rooftops), and along rural highways. Wet swales tend to be used for highway runoff applications, small parking areas, and in commercial developments as part of a landscaped area.

Because of their relatively large land requirement, enhanced swales are generally not used in higher density areas. In addition, wet swales may not be desirable for some residential applications, due to the presence of standing and stagnant water, which may create nuisance odor or mosquito problems.

The topography and soils of a site will determine the applicability of the use of one of the two enhanced swale designs. Overall, the topography should allow for the design of a swale with sufficient slope and cross-sectional area to maintain nonerosive velocities. The following criteria should be evaluated to ensure the suitability of a stormwater pond for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage – YES
- Suitable for High Density/Ultra Urban Areas – NO
- Regional Stormwater Control – NO

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 5 acres maximum
- Space Required – Approximately 10 to 20% of the tributary impervious area
- Site Slope – Typically no more than 4% channel slope
- Minimum Head – Elevation difference needed at a site from the inflow to the outflow: 3 to 5 feet for dry swale; 1 foot for wet swale
- Minimum Depth to Water Table – 2 feet required between the bottom of a dry swale and the elevation of the seasonally high water table, if an aquifer or treating a hotspot; wet swale is below water table or placed in poorly drained soils
- Soils – Engineered media for dry swale

Other Constraints / Considerations

- Aquifer Protection – Exfiltration should not be allowed for hotspots

3.2.6.5 Planning and Design Criteria

*The following criteria are to be considered **minimum** standards for the design of an enhanced swale system. Consult with Columbia County to determine if there are any variations to these criteria or additional standards that must be followed.*

A. LOCATION AND SITING

- A dry or wet swale should be sited such that the topography allows for the design of a channel with sufficiently mild slope (unless small drop structures are used) and cross- sectional area to maintain nonerosive velocities.
- Enhanced swale systems should have a contributing drainage area of 5 acres or less.
- Swale siting should also take into account the location and use of other site features, such as buffers and undisturbed natural areas, and should attempt to aesthetically “fit” the facility into the landscape.
- A wet swale can be used where the water table is at or near the soil surface, or where there is a sufficient water balance in poorly drained soils to support a wetland plant community.

B. GENERAL DESIGN

- Both types of enhanced swales are designed to treat the WQ_v through a volume-based design, and to safely pass larger storm flows. Flow enters the channel through a pretreatment forebay. Runoff can also enter along the sides of the channel as sheet flow through the use of a pea gravel flow spreader trench along the top of the bank.

Dry Swale

- A dry swale system consists of an open conveyance channel with a filter bed of permeable soils that overlay an underdrain system. Flow passes into and is detained in the main portion of the channel where it is filtered through the soil bed. Runoff is collected and conveyed by a perforated pipe and gravel underdrain system to the outlet. Figure 3.2.6-2 provides a plan view and profile schematic for the design of a dry swale system.

Wet Swale

- A wet swale or wetland channel consists of an open conveyance channel which has been excavated to the water table or to poorly drained soils. Check dams are used to create multiple wetland “cells,” which act as miniature shallow marshes. Figure 3.2.6-3 provides a plan view and profile schematic for the design of a wet swale system.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- Channel slopes between 1 % and 2% are recommended unless topography necessitates a steeper slope, in which case 6- to 12-inch drop structures can be placed to limit the energy slope to within the recommended 1 to 2% range. Energy dissipation will be required below the drops. Spacing between the drops should not be closer than 50 feet. Depth of the WQ_v at the downstream end should not exceed 18 inches.
- Dry and wet swales should have a bottom width of 2 to 8 feet to ensure adequate filtration. Wider channels can be designed, but should contain berms, walls, or a multi-level cross section to prevent channel braiding or uncontrolled sub-channel formation.
- Dry and wet swales are parabolic or trapezoidal in cross-section and are typically designed with moderate side slopes no greater than 2:1 for ease of maintenance and side inflow by sheet flow (4:1 or flatter recommended).
- Dry and wet swales should maintain a maximum WQ_v ponding depth of 18 inches at the end point of the channel. A 12-inch average depth should be maintained.
- The peak velocity for the 2-year storm must be nonerosive for the soil and vegetative cover provided.
- If the system is on-line, channels should be sized to convey runoff from the overbank flood event (Q_{p50}) safely with a minimum of 6 inches of freeboard and without damage to adjacent property.

Dry Swale

- Dry swale channels are sized to store and infiltrate the entire water quality volume (WQ_v) with less than 18 inches of ponding and allow for full filtering through the permeable soil layer. The maximum ponding time is 48 hours, though a 24-hour ponding time is more desirable.
- The bed of the dry swale consists of a permeable soil layer of at least 30 inches in depth, above a 4-inch diameter perforated PVC pipe (AASHTO M 252) longitudinal underdrain in a 6-inch gravel layer. The soil media should have an infiltration rate of at least 1 foot per day (1.5 feet per day maximum) and contain a high level of organic material to facilitate pollutant removal. A permeable filter fabric is placed between the gravel layer and the overlying soil.
- The channel and underdrain excavation should be limited to the width and depth specified in the design. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction, and scarified prior to placement of gravel and permeable soil. The sides of the channel shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling.

Wet Swale

- Wet swale channels are sized to retain the entire water quality volume (WQ_v) with less than 18 inches of ponding at the maximum depth point.
- Check dams can be used to achieve multiple wetland cells. V-notch weirs in the check dams can be utilized to direct low flow volumes.

D. PRETREATMENT / INLETS

- Inlets to enhanced swales must be provided with energy dissipators such as riprap.
- Pretreatment of runoff in both a dry and wet swale system is typically provided by a sediment forebay located at the inlet. The pretreatment volume should be equal to 0.1 inches per impervious acre. This storage is usually obtained by providing check dams at pipe inlets and/or driveway crossings.

- Enhanced swale systems that receive direct concentrated runoff may have a 6-inch drop to a pea gravel diaphragm flow spreader at the upstream end of the control.
- A pea gravel diaphragm and gentle side slopes should be provided along the top of channels to provide pretreatment for lateral sheet flows.

E. OUTLET STRUCTURES

Dry Swale

- The underdrain system should discharge to the storm drainage infrastructure or a stable outfall.

Wet Swale

- Outlet protection must be used at any discharge point from a wet swale to prevent scour and downstream erosion.

F. EMERGENCY SPILLWAY

- Enhanced swales must be adequately designed to safely pass flows that exceed the design storm flows.

G. MAINTENANCE ACCESS

- Adequate access should be provided for all dry and wet swale systems for inspection and maintenance.

H. SAFETY FEATURES

- Ponding depths should be limited to a maximum of 18 inches.

I. LANDSCAPING

Landscape design should specify proper grass species and wetland plants based on specific site, soils and hydric conditions present along the channel. Below is some specific guidance for dry and wet swales:

Dry Swale

- Information on appropriate turf grass species for Georgia can be found in Appendix F (*Landscaping and Aesthetics Guidance*).

Wet Swale

- Emergent vegetation should be planted, or wetland soils may be spread on the swale bottom for seed stock.
- Information on establishing wetland vegetation and appropriate wetland species for Georgia can be found in Appendix F (*Landscaping and Aesthetics Guidance*).
- Where wet swales do not intercept the groundwater table, a water balance calculation should be performed to ensure an adequate water budget to support the specified wetland species. See subsection 2.1.8 for guidance on water balance calculations.

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Reduced need for use of check dams
- High Relief – Often infeasible if slopes are greater than 4%

Soils

- No additional criteria

Special Downstream Watershed Considerations

- Aquifer Protection – No exfiltration of hotspot runoff from dry swales; use impermeable liner

3.2.6.6 Design Procedures

Step 1: Compute runoff control volumes from the Unified Stormwater Sizing Criteria.

- **A.** Calculate the Water Quality Volume (WQ_v), Channel Protection Volume (Cp_v), Overbank Flood Protection Volume (Q_p), and the Extreme Flood Volume (Q_f).
- **B.** Details on the Unified Stormwater Sizing Criteria are found in Section 1.3.

Step 2: Determine if the development site and conditions are appropriate for the use of a stormwater pond**.**

- **A.** Consider the Application and Site Feasibility Criteria in subsections 3.2.6.4 and 3.2.6.5-A (Location and Siting).

Step 3: Confirm Columbia County's design criteria and applicability.

- **A.** Consider any special site-specific design conditions/criteria from subsection 3.2.6.5-J. (Additional Site-Specific Design Criteria and Issues).
- **B.** Check with Columbia County officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4: Determine pretreatment volume.

- **A.** The forebay should be sized to contain 0.1 inches per impervious are of contributing drainage. The forebay storage volume counts toward the total WQ_v requirement, and should be subtracted from the WQ_v for subsequent calculations.

Step 5: Determine Swale dimensions.

- **A.** Size bottom width, depth, length, and slope necessary to store WQ_v with less than 18 inches of ponding at the downstream end.
  - Slope cannot exceed 4% (1 to 2% recommended)
  - Bottom width should range from 2 to 8 feet
  - Ensure that side slopes are no greater than 2:1 (4:1 recommended)
- **B.** See subsection 3.2.6.5-C (Physical Specifications / Geometry) for more details.

Step 6: Compute number of check dams (or similar structures) required to detain WQ_v.

Step 7: Calculate draw-down line.

- **A.** *Dry swale:* Planting soil should pass a maximum rate of 1.5 feet in 24 hours and must completely filter WQ_v within 48 hours.
- **B.** *Wet swale:* Must hold the WQ_v.

Step 8: Check 2-year and 25-year velocity erosion potential and freeboard.

- **A.** Check for erosive velocities and modify design as appropriate. Provide 6 inches of freeboard.

Step 9: Design low flow orifice at downstream headwalls and check dams.

- **A.** Design orifice to pass WQ_v in 6 hours. Use orifice equation.

Step 10: Design inlets, sediment forebay (s) and underdrain system (dry swale).

- **A.** See subsection 3.2.6.5-D through H for more details.

Step 11: Prepare Vegetation and Landscaping Plan.

- **A.** A landscaping plan for a dry or wet swale should be prepared to indicate how the enhanced swale system will be stabilized and established with vegetation.
- **B.** See subsection 3.2.6.5-I (Landscaping) and Appendix F for more details.

See Appendix D-5 for an Enhanced Swale Design Example

3.2.6.7 Inspection and Maintenance Requirements

Activity	Schedule
• For dry swales, mow grass to maintain a height of 4 to 6 inches. Remove grass clippings.	As Needed (frequent / seasonally)
• Inspect grass along side slopes for erosion and formation of rills or gullies and correct. • Remove trash and debris accumulated in the inflow forebay. • Inspect and correct erosion problems in the sand / soil bed of dry swales. • Based on inspection, plant an alternative grass species if the original grass cover has not been successfully established. • Replant wetland species (for wet swale) if not sufficiently established. • Inspect pea gravel diaphragm for clogging and correct the problem.	Annually (Semi-annually the first year)
• Roto-fill or cultivate the surface of the sand / soil bed of dry swales if the swale does not draw down within 48 hours. • Remove sediment build-up within the bottom of the swale once it has accumulated to 25% of the original design volume.	As Needed

Table 3.2.6-1 Typical Maintenance Activities for Enhanced Swales

(Source: WMI, 1997; Pitt, 1997)

Regular inspection and maintenance is critical to the effective operation of infiltration trench facilities as designed. Maintenance responsibility for this BMP should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval. **Columbia County will not accept ownership of or maintain this type of BMP.**

3.2.6.8 Example Schematics

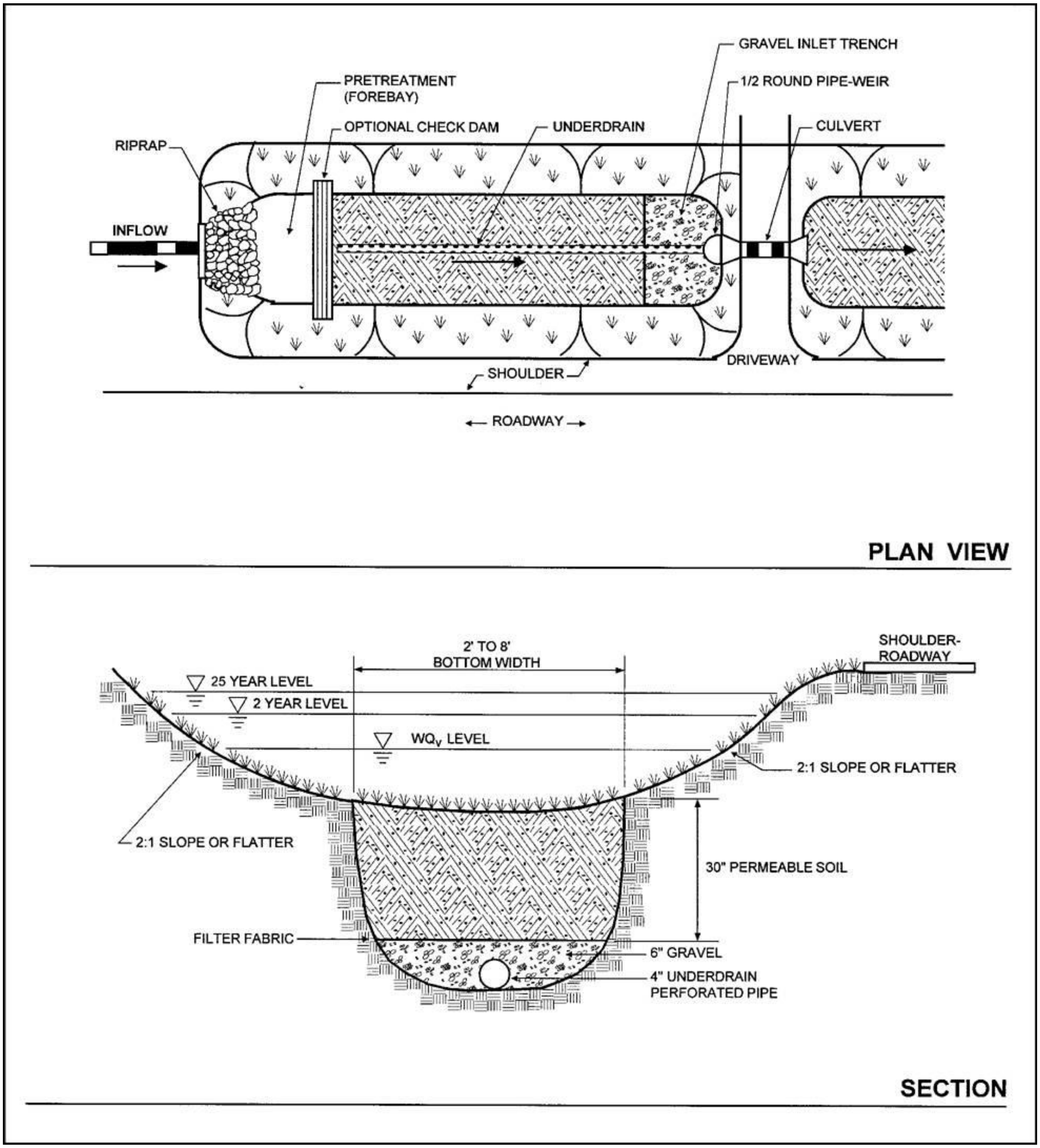


Figure 3.2.6-2 Schematic of Dry Swale

(Source: Center for Watershed Protection)

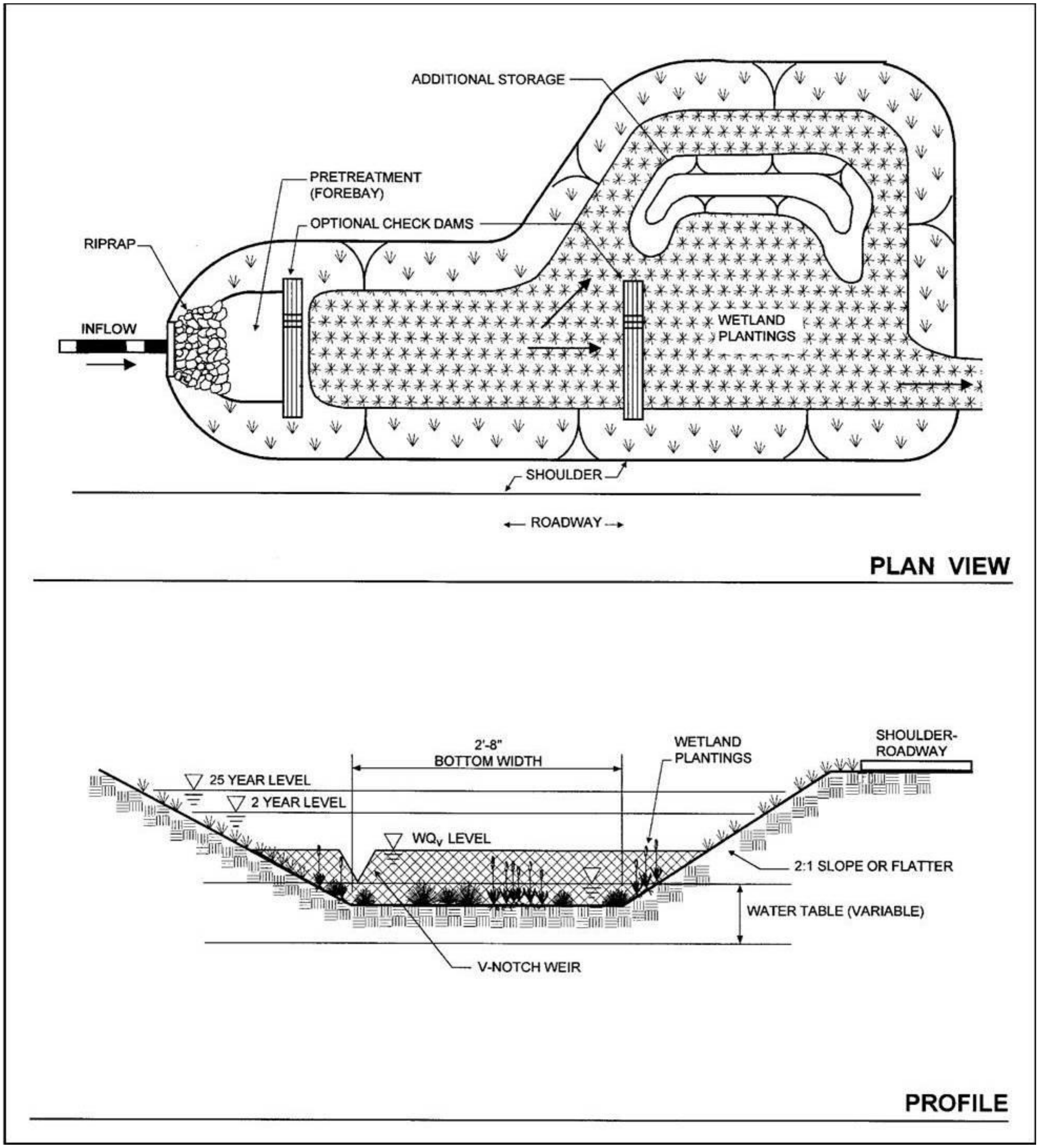


Figure 3.2.6-3 Schematic of Wet Swale

(Source: Center for Watershed Protection)

3.2.6.9 Design Forms

Design Procedure Form: Enhanced Swales

PRELIMINARY HYDROLOGIC CALCULATIONS			
1a) Compute WQ_v volume requirements			
Compute Runoff Coefficient, R_v	R_v =	______	
Compute WQ_v	WQ_v =	______	acre - ft
1b) Compute Cp_v	Cp_v =	______	acre - ft
Compute average release rate	release rate =	______	cfs
Compute Q_{p50}	Q_{p50} =	______	acre - ft
Compute (as necessary) Q_f	Q_f =	______	acre - ft
ENHANCED SWALE DESIGN			
2) Is the use of an enhanced swale appropriate?	**See subsections 3.2.6.4 and 3.2.6.5-A**		
3) Confirm local design criteria and applicability	**See subsection 3.2.6.5-J**		
4) Pretreatment Volume Vol_{pre} = I (0.1")(1'/12")	Vol_{pre} =	______	acre - ft
5) Determine swale dimensions Assume trapezoidal channel with maximum depth of 18 inches	Length =	______	ft
	Width =	______	ft
	Side Slopes =	______	
	Area =	______	ft^2
6) Compute number of check dams (or similar structures) required to detain WQ_v	Slope =	______	ft / ft
	Depth =	______	ft / ft
	Distance =	______	ft
	Number =	______	each
7) Calculate draw-down time Require k = 1.5 ft per day for dry swales	t =	______	hr
8) Check 25-year velocity erosion potential and freeboard Requires separate computer analysis for velocity	V_{min} =	______	fps
Overflow weir (use weir equation) Use weir equation for slot length ($Q = CLH^{3/2}$)	Weir Length =	______	ft
9) Design low flow orifice at headwall Area of orifice from orifice equation $Q = CA\,(2gh)^{0.5}$	Area =		ft^2
	diameter =	______	inch
10) Design inlets, sediment forebays, outlet structures, maintenance access, and safety features.	**See subsections 3.2.6.5 - D through H**		
11) Attach landscaping plan (including wetland vegetation)	**See Appendix F**		

Notes: ______________________________

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